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THE ANTICLINAL AND HYDRAULIC THEORIES OF OIL AND GAS ACCUMULATION.

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Oil in commercial quantities has been found in sandstones, limestones and shales, from a few feet to more than 3,000 feet below the surface. Pools in sandstones occupy soft porous lenses called pay streaks which occur within them. In only a relatively small per cent. of the oil pools does the production come from the entire thickness of sandstone. Many pools in pay streaks within sandstones of average grain, hardness and porosity do not show the slightest indication of being oil bearing until the bed has been penetrated for several feet and frequently not until the thin pay streak is tapped. In such cases wells sometimes fill up from 1,000 to 2,000 feet with oil and less often flow oil at the rate of from 10 to several thousand barrels per day. Pay streaks are the rule rather than the exception in sandstones, especially in those of the Appalachian region. They are usually comparatively thin, being seldom over one-third of the total thickness of the sandstone and frequently much less. The porosity of the pay streaks varies greatly in different sandstones and in different areas of the same bed. In one place the oil may occur in a coarse, pebbly, conglomeratic lentil, while a superimposed pool in another sand may occupy a pay streak less porous than the enclosing sandstone of the first pool. In all cases the pay streak is more porous than the rest of the sandstone.

The oil and gas pools in limestones generally occur in dolomitic portions made porous by interlocking crystals. These porous patches are apparently more nearly uniform over wide areas than the pay streaks in sandstones. Oil pools in shales are confined principally to fissures and joints, and to brecciated zones.

In this paper an attempt is made to state briefly the essential points of the Anticlinal and the Hydraulic theories, which are the two most important ones yet offered by geologists to account for these pools of oil and gas. In doing so no attempt will be made to accredit to each investigator the ideas essentially his own, or to give a detailed chronological account of the development of these theories.

ORIGIN.

In all attempts to provide a scientific explanation of the processes of accummulation of oil and gas their origin should first be taken into account. Upon this point many theories have been advanced, all of which may be grouped under two heads, inorganic and organic. The first is essentially the theory of chemists, who hold that oil and gas were probably formed by water coming in contact with deeply buried and hence highly heated carbides of iron, manganese or other metals. Under such conditions it is held that chemical reactions would take place whereby the hydrocarbon compounds of which oil and gas are composed would be formed. Certain of these compounds which closely resemble refined petroleum have been produced in the laboratory from cast iron. Small quantities of oil and solid paraffin have been discovered in certain lava flows. Gas has also been found in meteorites.

On the other hand geologists hold that while it is possible for oil and gas to be formed in nature from inorganic substances, by far the larger part of the enormous quantities enclosed in the sedimentary rocks, and probably all of that from which we obtain our supply, originated from organic matter. The amount of organic material which was entombed in these rocks when they were deposited is very great, and forms an appreciable percentage of the entire mass. The oil and gas which easily

might have been derived from this source and which are now diffused throughout the sedimentary rocks, exceed thousands of times that accumulated in pools of commercial size.

The preponderance of evidence favoring organic matter as a source of oil and gas is overwhelming. The remains of plants and animals which lived in these seas sank to the bottom and when partially decomposed were covered by succeeding deposits of sand and mud that later became compressed and cemented into sandstone and shales. At places in the sea where certain forms of animal life predominated, beds of lime were formed by the calcareous portions of their remains, while the softer parts of their bodies probably, under favorable conditions, produced large quantities of oil and gas. It is believed that oils showing a high percentage of sulphur and nitrogen were formed principally from animal matter. Other oils, while derived from both sources, are probably mainly vegetal in their origin.

Oil and gas indistinguishable from the natural product have frequently been made in the laboratory from both animal and vegetal matter. Scientists are not universally agreed, however, upon the processes through which this transformation took place in nature. Slow distillation of the organic matter at low temperature, and bacterial action under water and therefore in the absence of air, are generally considered to have been the agents of transformation.

We may therefore assume as a safe premise that all the oil and gas now obtained from sedimentary rocks originated in them and that a relatively small portion is now in pools of commercial value. With equal certainty we know that these pools are accumulations and that the oil has been brought together by natural processes from its originally widely diffused state. Somewhat less positively it is believed that the oil of pools collected in sandstones or shale has been accumulated from the shales. As to the source of the large oil deposits found in limestones geologists are not agreed. Some consider that the oil has been derived from the softer portions of animals the calcareous parts of which form the limestone, and that it is therefore indigenous.

Other geologists think that the oil has been collected into the porous dolomitic portions of limestones in the same way as that in sandstones and shales. It seems best to consider that limestone oils have been derived from both these sources.

THE ANTICLINAL THEORY OF OIL AND GAS ACCUMULATION.

Geologists who first made a study of the phenomena of oil and gas pools found that these substances were invariably contained in a porous bed beneath a close-grained, apparently impervious bed of shale. The oil bearing bed was also found in many cases to contain more or less salt water. With these facts established the conclusion was reached that the oil had come up from somewhere below and had been prevented from continuing on its way to the surface by the impervious bed of shale. The cause of this upward movement was attributed to "hydrostatic pressure" (which is the pressure exerted by a body of water at rest). This is interpreted to mean that the supposed upward movement of the oil and gas was caused by the difference in weight of the oil and gas, and salt water, thereby causing the lighter substances to travel upward through the rocks until stopped by some impervious bed. This was without question the fundamental idea involved in the anticlinal or structural theory of oil and gas accumulation. With it in mind the next deduction was that the most favorable places at which pools of oil and gas might occur were along the arches of anticlines, especially domes, in regions where the folding of the strata were not so profound as to cause joints and fissures in the impervious cover but still sufficient to give a gradient along which the oil and gas could travel in the porous bed.

Investigations showed that a large percentage of oil and gas pools were located upon and near the tops of domes, anticlines, and structural terraces, and that most pools showed unmistakable evidence of being affected by structure. These facts were assumed therefore to prove the correctness of the above deductions and to afford very positive proof that structure is an important factor of accumulation *because it offers an opportunity*

for the oil, gas and salt water to disassociate themselves through difference in gravity.

Many quotations might be cited from literature on this subject, but the following statement by the late Dr. Edward Orton,[1] State Geologist of Ohio, will suffice. Speaking of the oil and gas bearing sandstones of Ohio he says:

> If one of these sandstone strata filled with salt water, oil and gas and freely permeable laterally and horizontally for even miles at a time were to be thrown into a system of low folds, what effect would this movement have upon the contents of the strata? Would not a separation of gas, oil and water be sure to follow, the gas finding its way to the summits of the arches and the salt water sinking to the bottoms of the troughs? Such a result would be inevitable under the conditions assumed.

Therefore, assuming the presence of oil, the three essential factors involved in oil and gas accumulation according to this statement of the anticlinal theory are: (1) Saturation of the rocks of the collecting area by salt water, oil and gas. (2) Slight irregular folding of the strata. (3) A porous bed overlain by an impervious one.

The simplicity of this theory, its seemingly logical deductions, and its fairly successful practical application in various parts of the country, especially over large areas in Ohio, West Virginia, and some fields of southwestern Pennsylvania, have given it a wide recognition among both geologists and producers. Since this theory was formulated its application to explain the exact locations of pools from a detailed knowledge of the structure of the oil bearing beds, while frequently successful in a general way, has often left many apparently essential facts unexplained. In order to obviate these evident defects in the theory many suggestions and modifications have been offered by geologists working in the various fields of the United States. These suggestions fall into two general classes: (1) Those based upon the idea that movement towards accumulation is caused by the difference of gravity in oil, gas and salt water. (2) Those based upon the belief that other factors have played important rôles in the process of accumulation.

[1] Preliminary Report of the Geological Survey of Ohio, 1886, p. 13.

The modifications offered under the first head by the earlier writers are admirably summed up by Griswold in what is not only among the latest but also one of the most complete statements of the difference-in-gravity idea of accumulation yet made. He says:[1]

> Whether the petroleum comes from within or from below the shales, it must pass through them, and to do this it must pass through the very small pores existing in those relatively impervous beds. The nature and cause of this movement are not understood. Capillary action and great rock pressure may be suggested as causes which aid in forcing the petroleum out from the shales, but there are not sufficient data on this subject to justify any scientific explanation. It matters little what is the ultimate source of the oil; the important facts are its occurrence now in the porous sandstones, its circulation through the rocks, and the conditions leading to its accumulation in commercial deposits.
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> *Movements in Porous Rocks.*—The porous rocks into which the oil and gas enter may be dry, or they may be completely saturated with water. In most cases it is probable that a combination of these two conditions exists—that the porous rocks are completely saturated with water up to a certain level, but above that point they are dry. The movement of the hydrocarbons through the rocks will not be the same in the two cases, and therefore each condition must be considered separately.
>
> If small quantities of oil and gas enter a dry porous rock at different points the oil will flow down as long as gravity is sufficient to overcome the friction and the capillary attraction. The gas will diffuse with the air or water vapor contained in the pores of the rock.
>
> Oil and gas entering a porous rock that is completely saturated with water will be forced up to the top of the porous stratum by the difference in the specific gravity of the hydrocarbons and the water. Here the oil and gas will remain if the porous stratum be perfectly level, but if it has a dip sufficient to overcome the friction, the particles of oil and gas will gradually move up this slope, the gas with its lower specific gravity occupying the higher places.
>
> In case the porous rocks are partly saturated a combination of these two actions will take place. The oil entering above the line of complete saturation will flow down to that line and the oil entering below will be forced up to the top of the completely saturated portion.

In this statement it will be noted that provision is made for accumulation of oil into pools in dry rocks by the direct action

[1] Bulletin No. 318 U. S. Geological Survey, p. 13.

of gravity, and in rocks partly saturated and partly dry by a combination of the direct action of gravity and the force exerted upward by the difference of gravity of oil and salt water. While this theory seems very simple and practicable, its limitations are so extremely evident that its popularity can only be explained upon the ground that the formulation of a better hypothesis has not been seriously attempted.

Concerning the more glaring defects of this theory attention might be called to the fact that it makes no adequate provision to account for the enormous pressure developed in both oil and gas wells. What explanation is given for a pressure sufficient to flow from a sandstone 20,000 barrels of oil per day through a 6-inch hole 2,000 feet deep, or the production of more than 80,000 barrels of oil per day from a 6-inch hole drilled to a dolomitic limestone more than 1,000 feet below the surface? Again, the closed pressure of the better grade of gas wells is seldom less than 300 pounds per square inch and is frequently from 800 to 900 and even as high as 1,500 pounds to the square inch, some of the wells having a maximum daily capacity of more than 30,000,000 cubic feet. What explanation of this well-known phenomenon of pressure does the above stated theory make?

That such pressures can be secured by a difference of gravity of oil, water and gas, or through the weight of oil or gas in the producing sand, seems impossible. The maximum pressure possible to obtain in this way is by gravity direct, in beds standing vertically. Under such conditions this pressure would be equal to the weight of a column of oil through the vertical section of the saturated zone. The dip of the oil-bearing beds in the oil fields of the Appalachian region is seldom, if ever, more than 200 feet to the mile. In most pools it is less than 50 feet and the dip within the limits of a few very large pools is less than 30 feet to the mile. The greatest dip within the limits of oil pools in this region ranges from about 30 feet to about 150 feet. This gives therefore a maximum pressure in dry rocks ranging from about 10 to less than 55 pounds per square inch.

In saturated rocks the maximum pressure under the same circumstances would be limited by the lifting power of a body of oil floating on water, which, as shown by the writer in a previous article in ECONOMIC GEOLOGY,[1] is about 0.26 of the weight of the column of oil.

It has been suggested by geologists favoring this theory that pressure is caused by the generation of gas from oil within the pool after it is formed. This may be true, but since the theory provides that the oil is free to move towards the pool by gravity, what is to prevent the newly generated gas from forcing the oil back along this route, or else dissipate this pressure throughout the sandstone? When it is remembered that many oil pools located on the axes of anticlines, in places where no higher drainage areas are available in the oil sand, and from which no water is obtained, flow oil and gas freely through from 1,500 to 2,500 feet of two-inch pipe, it will be seen that the anticlinal theory as given above and as usually stated by geologists, furnishes no adequate explanation of the phenomenon.

The favorite bugbear to which most misapplications of the accumulation-by-gravity idea of the anticlinal theory are attributed by its adherents is the time-honored delusion—imperviousness of strata. Failures to locate or outline pools by mapping the structure of the oil bearing bed are too often attributed to the imperviousness of the oil sand. This is the orthodox way of dodging the point and it sometimes doubtless serves a useful purpose, but its abuse is not conducive to the progressive study of the problem involved in oil and gas accumulation. *No unaltered sedimentary rocks of the type in which oil and gas gas pools occur are impervious.* Every known fact regarding the lithologic character of the oil sands as a whole shows that from 10 to 40 per cent. of their bulk is made up of pore space. Data relative to the porosity of the enclosing beds of shales are less plentiful, but their pore space doubtless ranges from one to 15 per cent. with an average of not less than 6 per cent. This means that in every square foot of the so-called impervious beds

[1] "Studies in the Application of the Anticlinal Theory of Oil and Gas Accumulation," 1909.

overlying an oil and gas pool about 8½ square inches are holes The most impervious patches probably have from 1½ to 2 square inches of pore space in every square foot.

The anticlinal theory implies that oil pools have been accumulated very slowly, globule by globule, through a comparatively long geologic time. If this be true but little pressure could obtain in a pool before the oil would be forced out of the porous sandstone into the more dense but still quite porous shale as rapidly as it was mysteriously collected from the underlying shale, as provided for in this theory. The fact that hundreds of high pressure pools do exist under shale beds of average porosity and even in pay streaks enclosed by sandstones having a porosity of from 10 to probably more than 25 per cent., shows beyond doubt that this theory fails utterly to provide a clear explanation of this very essential feature.

As previously stated, the consensus of opinion among geologists is that most of the oil now accumulated in sandstones has come from associated shales where it was widely diffused in minute globules. Many undisputable facts tend to prove that this is true. The great affinity of oil for shale and its corresponding lack of affinity for sandstone, are well known. If crude petroleum and clay, of which shale is largely composed, be mixed in water, a considerable portion of the oil will attach itself to the particles of clay with such tenacity that it will settle to the bottom of the containing vessel with the clay, and remain submerged indefinitely. This affinity of oil for clay is, therefore, a constant force acting against movement of the oil from the shales to the sandstones. By what means then has this enormous quantity of oil in sandstones been transported from the shale? Early writers attributed this movement to "hydrostatic pressure." Griswold suggests capillary action and rock pressure as possible causes but dismisses the subject as being of comparatively little significance. In the writer's opinion this is the greatest and most fatal gap in the anticlinal theory. The problem of providing a clear-cut, definite explanation of this process is especially important since the same agents are very likely

responsible for the further collection of the oil into pools within the sandstones.

The anticlinal theory is therefore seen to be of questionable value in a theoretical study of oil and gas pools, since the idea of transportation-by-gravity upon which it is based, is without doubt erroneous. In attempting to secure a truer interpretation of the geologic facts now clearly established relative to oil and gas pools the writer has formulated a tentative working hypothesis which is intended to be especially applicable to the oil and gas pools of the Appalachian region, but which may also be found of value in the study of other fields. It is made up partly of points suggested by other geologists and partly from the result of investigations made by the writer. A brief outline of the essential features of this hypothesis is given below, but for lack of space no attempt will be made to present at this time the facts upon which these deductions are based.

THE HYDRAULIC THEORY.

The central idea of this theory is that the principal active agent of oil and gas accumulation is moving water under both hydraulic and capillary pressure. It assumes that oil and gas have originated from organic matter, both animal and vegetal, entombed in the sedimentary rocks when they were deposited. The relative amounts of such matter doubtless varied greatly from place to place in different beds; the shales having as a rule many time the amount contained in sandstones, and the limestones a greater percentage of animal matter than the shales and sandstones. The amount of organic matter also doubtless varied in quantity as well as in character, within the same beds, and in associated beds of similar composition. The transformation of this organic material took place by slow decomposition and distillation at low temperatures, and by bacterial action in the absence of air, the latter being the principal agent.

The greater portion of this oil was probably produced shortly after the rocks were deposited and when they were still unconsolidated, at which time bacterial action was greatest. The dis-

tribution of the oil was probably in the main proportional to the amount of organic matter deposited in the various beds, though in areas where physical conditions greatly favored bacterial action the reduction of the organic substances was more complete, thereby producing more or less variation in this ratio.

Except in rare instances, the amount of oil produced at any one spot formed a negligible proportion of the rock mass. It was probably distributed as tiny isolated globules throughout enormous quantities of shale, with a relatively small amount in sandstones.

The oil in those limestones that show evidence of great maceration of the calcareous material before the beds were formed, has probably been obtained either from associated portions of the limestone of from the enclosing shales and is therefore not indigenous as is the oil in limestones made up largely of shells.

It will be noted that the above premise relative to origin of oil varies little from that mentioned earlier in this article as being almost universally agreed upon by geologists. From this premise the following deductions seem logical, as they are in close harmony with the known facts.

THE PROCESS OF ACCUMULATION.

The oil generated in the loose mud and sand on the sea bottom very probably came off in microscopic globules. Because of the great affinity of oil for clay, each of these tiny globules immediately after being formed eagerly seized upon the first small particle of clay with which it came in contact and completely enveloped all exposed portions of it. At this stage the shales were soft, unconsolidated beds of mud completely saturated with water, the pores of each tiny particle of clay being filled with water. Globules of oil not closely associated with particles of clay when formed, being lighter than water, probably arose toward the surface. Many of these globules, together with others that were formed in the water, came in contact with and attached themselves to floating clay particles and with them

slowly sank to the mud below. In time this petroliferous mud became covered by a bed of sand and this in turn by succeeding beds until they lay buried probably thousands of feet below the ocean floor.

If it were possible to note the effect of this downward movement upon the oil in a particular bed of mud and the overlying sand, it would be seen that slow compression of both beds would take place, thereby causing considerable reduction of their volume. This reduction would at first affect only the size of the interstices between grains and would suffice to force out of the beds a certain portion of the water held in them. The water in the shale would take the course of least resistance and travel upward into the sandstone, and in doing so displace an equal amount of water originally held in the sand, which would be forced upward into the overlying bed.

When compression first began in the loose mud the interstitial water probably had ample room for movement between the particles of clay, without disturbing the oil. However, as the bed becomes more compact the particles of clay were pressed more closely together and the oil films surounding them were brought to occupy a certain portion of the interstices of the shale. Water in the pore spaces of the individual clay particles to which the oil was first attached, still remained undisturbed. This compression of the shales doubtless continued until the oil was confined with water in the interstices of the shale. Under such conditions it could then be torn from its moorings by the upward currents of water through the interstices, and forced along into the sandstone as a more or less complete emulsion of oil and water.

The upward movement of a given particle of oil under such conditions continued only to a point where the pressure created by this compression was relieved. If the open space of the overlying sand equaled or exceeded in vertical section that of the mud, all of the oil and water which left the mud remained in the sand, displacing an equal amount forced into the next higher bed. The rate of compression which converted the oil-

bearing sands and muds into sandstones and shales doubtless was greatest at moderate depths and under relatively light loads. In many cases, however, subsidence continued until the beds under consideration were buried by thousands of feet of younger sediments. Under such conditions compression, cementation and increasing heat probably combined to cause further upward movement of the oil and water. *The general effect of this movement was to increase the percentage of oil in the sandstones at the expense of the shale, and to lose from the beds a greater ratio of water than oil, which further increased the percentage of oil to water in the sandstone, yet probably leaving a large amount of oil in the shales.*

The vicissitudes through which the various oil bearing beds have passed since their deposition are not told as simply as that given above, and to outline, even briefly, their geologic history, is beyond the province of this paper. We may take, however, a simple example, say that of the Appalachian region, and illustrate the principle upon which the hydraulic theory is based.

We may leave out of account, as unessential, the subsequent history of a given series of oil-bearing shales and sandstones of this region, from the time they reached their maximum depth and temperature until the present time, and be able to deduce from facts now clearly established a fairly complete account of the process of oil and gas accumulation which took place in them.

The drill has penetrated the sedimentary rocks of the Appalachian region to a depth of more than one mile and many wells have gone more than 4,000 feet into them. They have everywhere been found to consist of unaltered sandstones and shales of average porosity. Another fact of great theoretical importance is that the amount of water found in these rocks invariably decreases with depth. Fresh water is found in appreciable amounts in one or more beds as a rule to a maximum depth of 200 to 800 feet. Brackish or salt water occurs below the fresh water at depths ranging from 400 to about 3,000 feet. In a few wells out of the thousands drilled, salt water was found at greater depths than 3,000 feet, but in all such cases the

amount and head of this water was very small, regardless of the porosity of the containing bed. In many wells open porous sandstones from 1,000 to 3,000 feet from the surface show no water. Many of these were found to take up, with surprising rapidity, water poured into the well in the process of drilling. It is a generally recognized fact among oil men that as a rule *the volume and head of water in a given bed decreases with increasing depth from the surface.* Examples are numerous in the deeper sands where the supply of water in a given bed *entirely disappears* when traced down the dip. Fresh water in beds relatively close to points of outcrop shows a steady change to salt when traced down the dip.

These water conditions in the oil and gas bearing rocks of the Appalachian region obtain over thousands of square miles. These facts appear more remarkable when it is remembered that this oil region is located near the axes of a very broad shallow synclinorium or trough lying between the Allegheny Front on the east and the Cincinnati Anticline on the west, and extending from New York to Tennessee. This trough has doubtless existed since Permian times, and is probably much older. As previously stated the maximum dip within this oil and gas region is probably not more than 200 feet to the mile, the average not exceeding 75 feet per mile.

Four points of very great theoretical importance relative to the present water conditions in the oil and gas bearing beds are clearly established by the facts referred to above: (1) These oil-bearing shales and sandstones have lost such an amount of their original water of deposition that they are now unsaturated in places. (2) The water now found in these beds is partly meteoric and partly water of deposition. (3) Most of the original water of deposition in these rocks is held in them by capillarity, which would not permit the water to drain into a well drilled into it. (4) The salt water is largely water of deposition collected by being forced ahead of and with moving bodies of meteoric water.

As regards the first point, it is an open question among

geologists as to how and when these rocks became unsaturated. The explanation of this fact is by no means a simple one. This is especially true of some of the deeply buried oil sands which take up water with such avidity as to lead to the conclusion that the moisture in them must fill a very small percentage of the available pore space. It has been suggested that these rocks lost most of their water as steam and water vapor when they were at or near their greatest depth and temperature. Hydration, expansion of the beds upon a partial release of pressure, and differential contraction of the rocks and their fluid contents upon cooling, have been suggested as possible causes. An explanation of this phenomenon, however, is not germane to the statement of the hydraulic theory. *The essential fact is that all of these rocks are not at present saturated with water.* Whatever the agent of this depletion might have been, it was certainly one of diffusion rather than of accumulation and concentration, and may therefore be dismissed as not being the cause of the collection of oil and gas into pools. It seems very probable that the oil and gas pools which we find in the rocks to-day were formed subsequent to the desaturation of the oil and gas bearing beds.

As stated in the beginning, the fundamental idea of the hydraulic theory is that moving water under either hydraulic or capillary pressure has been the direct agent of accumulation of oil and gas pools. To this idea may be added another of equal value—the pools of oil and gas are held in place by water under hydraulic and capillary pressure which effectively seals up all the pores of the surrounding rock and prevents the dissipation of pressure by diffusion. Around these two fundamental principles must yet be grouped the essential facts needed to round out this hypothesis and to provide a more complete explanation of all the phenomena observed in the development of oil and gas pools. At the present time sufficient detailed facts relative to oil and gas are not available to establish any theory beyond question. In a general way, however, it may be shown that this theory offers several advantages over that involved in the

difference-in-gravity idea of accumulation which is unquestionably the principle upon which the anticlinal theory is based: (1) It provides an adequate means of forcing the oil and gas from the shales into the pay streaks of the sandstones or other porous beds. (2) It provides a means of preventing diffusion by sealing up the pore space surrounding oil and gas pools by water under either hydraulic or capillary pressure. (3) It provides an ample source of pressure in both oil and gas pools. (4) It furnishes a better explanation of the structural position of pools of oil and gas, especially in the Appalachian region.

The exact way in which moving water collects pools of oil and gas, as provided for in the hydraulic theory, may be made clearer by brief reference to a few well-established facts relative to the movement of water by hydraulic pressure and capillarity. Water traveling by hydraulic pressure is forced along by the weight of the column of water above. It will, therefore, travel fastest and farthest in the rocks having the largest capillaries, fissures and joints, since under such conditions friction, which opposes such movement, is least. Conversely it will travel slowest in the rocks having the smallest capillaries or pores, because the friction is greatest. The effect of friction is to decrease the rate of movement and the active head at the edge of the saturated area as it spreads farther and farther away from the point of intake or the source of water supply. In a given case this element of friction would affect the pressure at every point until the whole basin below the intake was entirely filled and the body of water was brought to rest upon an absolutely impervious bottom. The pressure would then become hydrostatic and not hydraulic, and all points of equal distance below the intake would have the same pressure regardless of the nature of the rock. At a given spot water may therefore penetrate the rocks to where the combined friction entirely overcomes the hydraulic pressure at that point, thereby reducing the rate of movement to zero, without introducing the hydrostatic element of pressure.

Water moving by capillarity has been described as "*drawing*

itself along in an endeavor to fill capillaries." This statement is not an exactly true one, since the forward movement is probably entirely due to pressure exerted by the water from the walls inward, being in effect a "squeeze" rather than a pull. The capillary force of water increases greatly with a decrease in the size of the capillaries. The finest grained rocks furnish the best avenues for movements by capillarity.

Water moving through rocks therefore travels both by squeezing itself along by capillarity and by being forced along by the weight of the column of water above, minus the friction. These forces evidently act in concert. In open porous beds the hydraulic element probably predominates, while in close fine-grained rocks movement is largely capillary. In all instances where the hydraulic element is active the advancing water is preceded by a skirmish line of capillary water. When the hydraulic element is exhausted by friction, the line of saturation is extended to a greater or less distance beyond to a point where the friction becomes so great that the supply of water for forward movement by capillarity cannot be brought up from the rear. When a bed is once invaded and saturated through capillary movement, the water of saturation cannot exert itself further; it can be forced out of the capillaries only by hydraulic pressure. The movement of such water in a capillary is subject at all times to the same laws of friction as that forced along by hydraulic pressure.

Water moving from a given intake, or other source of supply, and traveling by hydraulic and capillary pressure as described above, would completely saturate the beds as it advanced, and, because of its greater capillary force, would accumulate and push ahead of it a considerable portion of the oil and gas contained in the beds. *Movement through the different beds would not be uniform, which would finally result in zones of conflicting currents of water between which the bodies of oil and gas would be trapped and held.* Water passing through a shale by capillarity would force oil into a sandstone or other porous bed below, where capillarity would be too weak for the water to

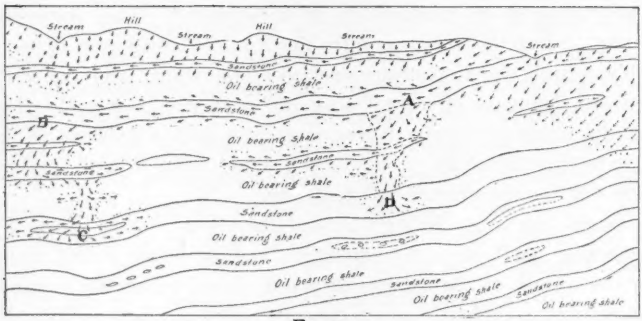


FIG. 77.

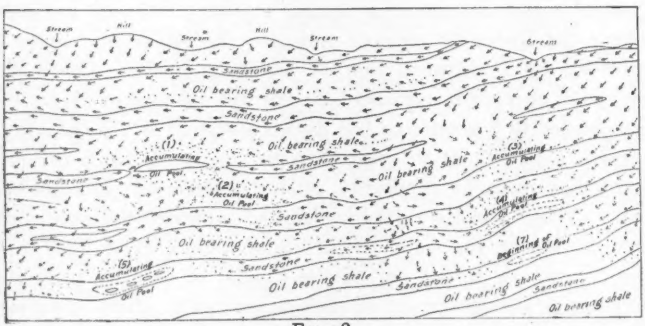


FIG. 78.

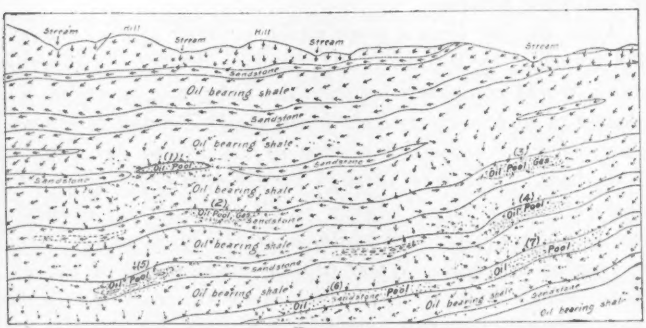


FIG. 79.

follow. If portions of the sandstone should happen to be fine-grained, while other portions were conglomeratic and unusually porous, the tendency of capillary movement would be to force the oil from the denser into the more porous portions, which would constitute the "pay streaks" as they are now found. While some pools would thus be formed by capillarity alone, others would be collected entirely by hydraulic pressure, and still others by a combination of hydraulic and capillary movements.

Therefore the general result of such movement would be to form a large number of oil and gas pools in all kinds of rocks and under many varying conditions. Those pools of commercial value would be the ones formed in relatively porous beds under high pressure. This pressure while now sometimes found to be partly hydraulic was originally mainly capillary. *Pressure in pools is maintained by the expansive force exerted by gas, which was either accumulated with the oil or generated subsequent to the formation of the pools. Such gas could not diffuse because of the saturated condition of the surrounding rocks.* Pools in which the hydraulic element is active show more or less water with the oil and gas. Those which were accumulated by capillarity would show no indication of water, nor would water appear in a well drilled through beds enclosing capillary water. A combination of the hydraulic and capillary elements of pressure in different proportions results in all gradations from rocks showing considerable quantities of water to those apparently dry, though in fact filled with capillary water. Such areas should not be confounded, however, with those that have not been invaded by moving water and in which the rocks are still unsaturated.

FIGS. 77, 78 and 79 show an ideal section through a series of oil and gas bearing shales and sandstones of the Appalachian type, and the approximate course taken by an invading body of water. The arrows indicate the supposed direction of movement of the water through the rocks. Solid arrows show areas under hydraulic pressure. Dotted arrows show where the movement is supposed to be entirely or largely capillary. Dots show favorable points for the accumulation of oil and gas.

The principle upon which the hydraulic idea of accumulation is based is illustrated by Figs. 77, 78 and 79, which are intended to show three stages of an invasion by surface waters of a series of sandstones and shales containing oil and gas in fields similar to those of the Appalachian region. Fig. 77 shows a sandstone outcropping at the surface to be the principal source of water. This sandstone is underlain by shale which at certain points, *A* and *B*, is assumed to be more porous and therefore more easily penetrated by water traveling under hydraulic pressure than the denser portions of the shale. Under such conditions the water traveling principally by hydraulic pressure through the sandstone and through the porous portions of the shale might easily reach the points, *C* and *D*, in the lower sandstone before the denser shale at other points had been saturated. From these points the direction of the moving water as indicated by the arrows, would result ultimately in the collection of bodies of oil and gas from the rocks through which the water passes into areas surrounded by opposing currents of water. As long as this water moves by hydraulic pressure pools of commercial size will result from the accidental meeting of such currents around pay streaks. In areas where capillary movement predominates the battle for capillary space between the water and the oil will go on until the water ultimately forces the oil into the more porous portions of the rock where capillary attraction is weakest.

It may be seen that the capillary pressure of water enclosing a gives pool may be augmented by hydraulic pressure by subsequent erosion and a greater invasion of water. It is also possible for enormous quantities of oil and gas to have been driven downward through the rocks for relatively great distances before being finally trapped by conflicting currents. When once formed, however, pools remain practically stationary.

The above sketches may be modified to fit the local conditions found in a very large number of pools of much more intricate structure, without in the slightest degree changing the principle upon which they are based. Instead of a common source of water there may have been as easily a number of independent

sources of supply, which may be either meteoric water, or water of deposition, or both. Again, each unconformity represents a time when there was a possibility of an invasion of surface water being followed by salt water from the unlimited supply of an encroaching sea.

In all cases the geologic history of an oil or gas pool is intimately associated with the structural changes to which the bed enclosing it has been subjected. The structural position of a pool may therefore be said to depend upon the direction of movement of the invading water with reference to the dip of the rocks. If the course of the water was parallel to the dip of the rocks and the movement by hydraulic pressure, the position of the oil pool will conform fairly closely to structure lines. If the movement with the dip was by capillarity this conformation to structure would be more modified by the varying porosity of the oil bearing bed. If the moving water had a direction parallel to the strike the pools may have no definite structural arrangement.

The salt water so often found in connection with oil and gas may be either the original water of deposition, or it may be surface water which has traveled a sufficient distance through the beds to accumulate salt from the rocks by solution. In most cases the salt water probably is derived from both sources.

The practical application of the hydraulic theory in the search for new pools of oil and gas, especially in the Appalachian fields, involves an intimate knowledge of the structure, stratigraphy and the general water conditions of the various beds, and all the facts relative to the varying porosity of the beds that may be acquired. With this knowledge a trained geologist familiar with the geologic problems involved in any particular field, should be able to consistently select areas for testing where the possibility of pools having been accumulated is far above the average. The value of such work will of course in all cases be dependent upon the information available and upon the ability of the one who interprets it.

THE IRON ORES OF MARYLAND.[1]

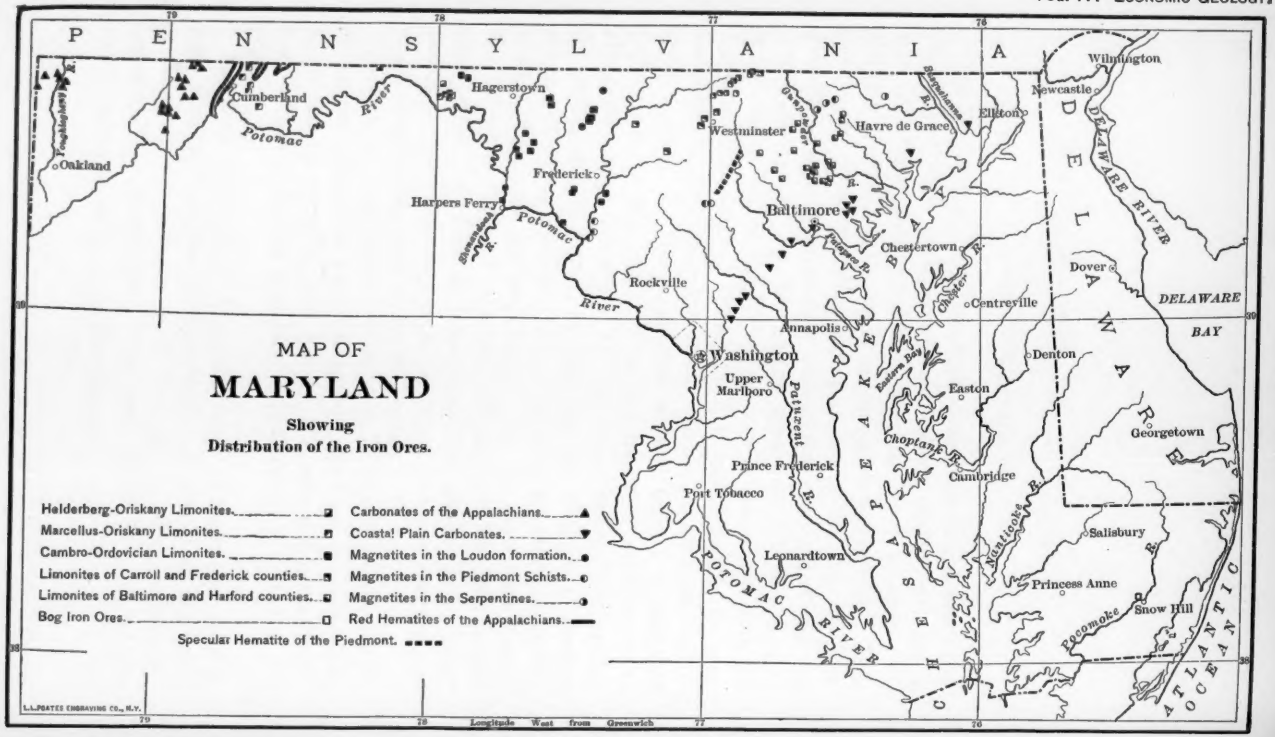
JOSEPH T. SINGEWALD, JR.

The iron industry of Maryland dates back to the early part of the eighteenth century, and until about thirty years ago it was one of her most important industries. In 1761 there were eighteen furnaces in Maryland operating on native ores. During the Revolutionary War and again during the War of 1812, Maryland furnaces turned out cannon and cannon balls for the American Armies. J. M. Swank says that Allegany County is entitled to two of the highest honors in connection with the American iron trade. "It built the first successful coke furnace, and rolled the first heavy iron rails." In 1874 there were twenty-eight furnaces in Maryland with a total annual capacity of 94,000 tons of pig iron. This was the high water mark in Maryland's iron industry. In 1870 she ranked fifth among the iron-producing States; by 1880 she had dropped to twelfth place; and to-day only one furnace running on native ores survives, and that has not been in operation for more than a year. The output of the latter, the Muirkirk furnace, has been largely used by the United States Government, the product being guaranteed to stand 30,000 pounds per square inch in the pig and often withstanding on test 40,000 pounds.

In view of these facts, the question as to Maryland's future in the iron industry is a most important one from the standpoint of her natural resources, and it is for this reason that the Maryland Geological Survey is making a study of the iron ores of the State.

The four chief ores of iron are known to occur and have at some time been worked in Maryland. Arranged in the order of their importance in the State, they are limonites, carbonates, hematites and magnetites. The map, Plate VII, shows the

[1] Published by permission of the State Geologist.



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distribution of these ores. Limonites are found on the Appalachian, Piedmont and Coastal Plain areas. They attain their greatest development in the Piedmont and the eastern portion of the Appalachian area. Carbonates occur in the Appalachian region and in the Coastal Plain. The carbonates of the Appalachian region are found in the Coal Measures of Western Maryland. The Coastal Plain carbonates are in the Arundel formation along the western edge of the Coastal Plain. Hematites occur in two varieties, red hematite and specular hematite. The red hematite occurs in the Clinton formation of the Appalachian region. The specular hematite occurs in the Piedmont in a quartz vein in Carroll County. Magnetites are found only in the Piedmont and along the eastern edge of the Appalachian region.

THE LIMONITES.

The limonites are by far the most important iron ores in Maryland. Geologically considered they fall into four distinct groups, which, arranged according to their geographical distribution in the State from west to east, are the following: (1) Devonian limonites. (2) Cambro-Ordovician limonites. (3) Limonites associated with the crystalline limestones of the Piedmont. (4) Bog iron ores.

None of these ores are original deposits, but they are all due either to a residual concentration of ferriferous materials or to direct replacement of other rock by ferriferous solutions. It is also a significant fact that nearly all of these deposits occur closely associated with limestone, demonstrating the important part played by calcium carbonate in the formation of such iron ore bodies.

DEVONIAN LIMONITES.

The Devonian limonites are found in the Appalachian region in Allegany and Washington Counties. They occur at two horizons, at the Helderberg-Oriskany contact and at the Oriskany-Marcellus contact.

Helderberg-Oriskany Limonites.—The "Oriskany ores" of Virginia occur at this horizon, but in Maryland it is of no par-

ticular importance. There is a promising deposit three miles northwest of Hancock but its extent is unknown, as no attempt has been made to prospect it. On the west side of North Mountain is the only occurrence of this ore that has been worked.

ANALYSIS OF HELDERBERG-ORISKANY LIMONITE.[1]

Fe	43.42
SiO_2	23.16
Al_2O_3	2.75
Mn	little
P	.16
S	.16
Ignition	9.00

Marcellus-Oriskany Limonites.—These ores are formed by the replacement of the limestone bands near the base of the Marcellus and are found at many points throughout the areas in which these rocks outcrop. On account of the thinness of the limestone bands, usually not exceeding six inches in thickness, the ores are generally of no economic importance. They have been worked in Allegany County near Cumberland, and in Washington County southwest of Clear Spring in the North Mountain region. In the latter region the deposits attain considerable size owing to the local thickening of the limestone beds into lenses of more than ten feet in thickness.

ANALYSIS OF MARCELLUS-ORISKANY LIMONITE.

Fe	45.79
SiO_2	18.37
Al_2O_3	3.98
Mn	little
P	.51
S	.10
Ignition	10.72

CAMBRO-ORDOVICIAN LIMONITES.

These ores are found in eastern Washington County and Western Frederick County. Three types of deposits occur un-

[1] The analyses accompanying this article were made in the laboratory of the Maryland Geological Survey by Mr. E. G. Zies and Mr. E. E. Gill, of the Johns Hopkins University.

der this head, the first type includes those at contact of the Shenandoah limestone with other formations. The second type consists of residual deposits in the limestone itself away from other rocks. In the third type are placed those deposits which occur in the Cambrian formations apparently unassociated with limestone.

Limestone Contact Deposits.—The limestone contact deposits are the most important of the three types of Cambro-Ordovician limonites and include the two most extensively worked ore bodies in the State—the Maryland Bank on the Potomac River northwest of Harpers Ferry and the Catoctin deposits at Catoctin Furnace in Frederick County. Moreover, most and especially the largest of the deposits under this type are not simple contact deposits, but are fault contact deposits, as is the case at the Maryland Bank and at Catoctin Furnace. It thus follows that these deposits attain their chief development in the faulted areas of the South Mountain region. West of Hagerstown there is a belt of Martinsburg shale crossing the State conformably overlying the Shenandoah limestone, but no ore deposits are known along these contacts. Further west, at the edge of North Mountain, where the Shenandoah limestone is faulted into contact with the Romney shales, ore deposits again occur. The significance of this connection of the ore deposits with faults is readily seen from their origin. The leaching of the shales in the process of weathering gives rise to ferriferous solutions. As these solutions come into contact with the limestone their iron content is precipitated. If the contact between the shales and the limestone is a fault contact, the shattered zone thus produced furnishes an area along which there will be abundant infiltration of the percolating waters, and as they enter this zone, they will deposit their iron content.

The ores of this type occur in Washington County along the western edge of the Hagerstown Valley at the foot of North Mountain where the Shenandoah limestone is faulted against the Romney shales; and along the eastern edge of the Blue Ridge where the limestone is faulted against the Harpers shale.

In Frederick County they occur along the west edge of the Frederick Valley at the foot of Catoctin Mountain where the limestone is faulted against the Loudon shale.

AVERAGE OF ANALYSES OF SEVEN SAMPLES OF LIMESTONE CONTACT LIMONITES.

Fe	41.25
SiO_2	19.92
Al_2O_3	6.03
Mn	1.12
CaO	.67
MgO	.56
P	.42
S	.09
Ignition	11.04

Residual Deposits in the Shenandoah Limestone.—Only a few small deposits of this type occur in Maryland and they are confined to the limestone of the Hagerstown Valley in Washington County.

Limonites in the Cambrian Shales.—The deposits of this type occur in the western part of Frederick County along the foot of Catoctin Mountain and in a small valley parallel to the Frederick Valley on its eastern side south of Frederick junction. The most important of these are at Point of Rocks where an almost continuous series of ore bodies have been worked for a distance of over three thousand feet.

ANALYSIS OF LIMONITE FROM POINT OF ROCKS.

Fe	38.50
SiO_2	21.23
Al_2O_3	5.12
Mn	2.11
P	.37
S	.06
Ignition	12.33

LIMONITES ASSOCIATED WITH THE CRYSTALLINE LIMESTONES OF THE PIEDMONT.

The limonites associated with the crystalline limestones of the Piedmont form the most important class of ore deposits in the State. They fall into two distinct groups. In Carroll and

Frederick Counties they occur at or near the contact of the limestones with schistose volcanic rocks of Archean age. In Harford and Baltimore Counties they occur either at or near the contact of the limestones with quartzites and schists probably of Cambrian and Ordovician age, or on the limestones overlain by the Lafayette formation of Pliocene age.

Limonites of Carroll and Frederick Counties.—The ore deposits of this group are found in what is known as Bachman Valley, which extends from Lineboro at the State line, to Westminster in Carroll County, and continue for some miles to the southwest into Frederick County. The greater part of the area is underlain by acid and basic schistose rocks of volcanic origin. Within this area of volcanics the limestones outcrop in a series of narrow strips in the stream valleys where they have been brought up by sharp anticlinal folds and the overlying volcanics eroded through. It is along the edges of these limestone outcrops that the ore deposits occur. Nearly all of them are located in the volcanics at the contact with the limestones. There are a few that do not occur at surface contacts but these are usually on the continuation of the strike of an outcrop of limestone or in some other position which makes it probable that the limestone occurs but a short distance below the surface. The volcanic rocks at the ore deposits are thoroughly leached and disintegrated and readily fall apart into a peculiar lead gray paper shale.

Recent prospecting in the Bachman Valley has disclosed a number of new deposits and this is one of the most promising areas in the State.

AVERAGE OF ANALYSES OF SIX SAMPLES OF BACHMAN VALLEY LIMONITES.

Fe	48.53
SiO_2	6.37
Al_2O_3	4.16
CaO	.69
MgO	.30
Mn	2.06
P	1.19
S	.05
Ignition	13.88

Limonites of Baltimore and Harford Counties.—These deposits geologically considered comprise two groups. The first group consists of those deposits occurring at the contact of the limestones with the underlying Setter's quartzite and the overlying Wissahickon schist. They are found in both Harford and Baltimore Counties. The second group consists of deposits occurring in the limestones themselves with a covering of Lafayette sand and gravel. These are confined to Baltimore County.

(*a*) *The Contact Deposits.*—The contact deposits are most numerous in the limestone areas of Baltimore County and Harford County in the northern and northwestern part, farthest removed from the Coastal Plain. The most extensively worked deposits of this group were those at Oregon in the Washington Valley in Baltimore County.

AVERAGE OF TWO ANALYSES OF CONTACT DEPOSIT LIMONITES.

Fe	52.80
SiO_2	8.01
Al_2O_3	2.98
Mn	little
P	.44
S	.12
Ignition	12.33

(*b*) *Deposits Overlain by the Lafayette Formation.*—These deposits derive their iron content from the iron originally contained in the Lafayette materials. As waters percolated through these loose ferruginous materials, the iron was leached out of them. When the iron bearing solutions came into contact with the underlying limestone, their iron content was precipitated. In this way many pockets of ore have been formed under the capping of outliers of the Lafayette formation. Deposits of this kind were worked at many points at and to the northeast of Lutherville and to a small extent in the vicinity of Towson.

ANALYSIS OF ORE OVERLAIN BY LAFAYETTE FORMATION.

Fe	46.40
SiO_2	15.72

Al_2O_3	4.95
Mn	little
P	.22
S	.08
Ignition	11.64

BOG IRON ORES.

Little is known at present as to the occurrence and extent of bog ores in Maryland. A furnace was formerly run on these ores in the extreme eastern part of the State, in Worcester County near Snow Hill.

THE CARBONATES.

CARBONATES IN THE APPALACHIANS.

The carbonate ores of the Appalachian region occur in the Coal Measures as "clay ironstone" and as "blackband." The blackband ores are of no importance in Maryland and apparently have never been mined. The clay ironstone occurs abundantly as nodules in the shales of the Coal Measures, but the layers are very irregular in thickness and extent. On the weathering of the shales the concretions are concentrated at the surface, and as these surface concentrations are exposed to weathering they alter to limonite. A large part of the ore that has been mined from these horizons in Maryland consisted of such altered ore. The following analyses of clay ironstone ores, one from Allegany County and one from Garrett County, show a fairly uniform composition.

ANALYSES OF CLAY IRONSTONE.

	Garrett Co.	Alleghany Co.
Fe	34.58	36.05
SiO_2	13.78	13.53
Al_2O_3	4.29	6.47
Mn	1.36	.94
P		.08
S	.49	.42
Ignition	24.11	25.02

When these ores were mined they were usually roasted before being put in the furnace, so that they ran about 47 per cent. Fe, and were practically free from sulphur.

Although the Coal Measures occur in five basins in Maryland, iron ores have been worked in only two of these, the Lower Youghiogheny and the George's Creek. The ores occur at many horizons throughout the Coal Measures, but those of the Pottsville formation are of little importance. In the Lower Youghiogheny basin the Allegheny formation and the lower part of the Conemaugh formation are the ore bearing horizons. In the George's Creek basin both the Conemaugh and Monongahela ores are important. The horizon that has yielded the most ores in this basin is a bed varying from eighteen inches to four feet thick, fifty to one hundred feet above the Pittsburg coal.

CARBONATES IN THE COASTAL PLAIN.

The carbonates of the Coastal Plain occur in the Arundel formation which is the upper member of the lower division of the Potomac group, and are hence either of Upper Jurassic or Lower Cretaceous age. They occur as a series of large and small lenses of iron ore bearing clays which occupy unconformably ancient depressions in the surface of the underlying Patuxent formation. Scattered through these clays are vast quantities of nodules of iron carbonate, at times reaching many tons in weight. In the upper portion the carbonates have weathered to limonite.

These ores occur along the western margin of the Coastal Plain and have been worked at many points from Cecil County to the District of Columbia. The famous Muirkirk iron is made chiefly from these ores.

THE HEMATITES.

RED HEMATITES OF THE APPALACHIAN REGION.

The red hematites of the Appalachian region occur in the Clinton formation and are generally known as the Clinton ores. With the exception of two small outcrops in Washington County west of Hancock, which are of no economic importance, the Clinton ores are confined in Maryland to Allegany County, flanking three anticlinal folds, forming Wills, Tussey and Evitts Mountains.

The ores occur at two horizons, each of which has its characteristic ore. Both appear oolitic; but the upper ore which occurs at the top of the Clinton is very fossiliferous, whereas the lower ore which occurs at from 120 to 160 feet above the base of the Clinton carries but few fossls. The thickness of the upper ore varies from four to nine inches. It occurs about the top Clinton sandstone and is usually separated from it by a bed of impure silicious limestone. The ore grades into the underlying limestone and frequently contains fragments of unreplaced rock. The amount of this ore calculated to a depth of a hundred feet is about 1,200,000 tons. The lower ore usually consists of two beds separated by a shale parting of variable thickness. In the western part of the County the total thickness of the ore beds reaches as much as thirty feet, coming eastward the thickness decreases to six or eight feet. The seeming oolites are merely more or less rounded, water-worn quartz grains which are held together in a matrix of ferric oxide. The composition of this ore shows that it can hardly be looked upon as more than a highly ferruginous sandstone. Its amount calculated to a depth of a hundred feet is about 24,000,000 tons.

ANALYSES OF CLINTON ORES.

	Upper Ore.	Average of Two Analyses of Lower Ore.
Fe	37.37	22.75
SiO_2	15.05	53.36
Al_2O_3	9.89	3.31
CaO	9.09	
MgO	.93	
Mn	.30	.22
S	.06	.05
P	.51	.23
Ignition	10.41	5.06

Mining has been confined to the upper ore and also to the Wills Mountain area. On the east limb of the Wills Mountain anticline the entire surface outcrop has been mined by stripping and considerable underground work done. On the west limb the ore has been mined for over a mile along the outcrop in the neighborhood of Cumberland.

A discussion of the origin of the Clinton iron ores in Maryland is far beyond the limits of this paper. This question will be fully discussed in the report on the iron ores of Maryland to be issued by the Maryland Geological Survey. The evidence now at hand is all in favor of original deposition for the lower Clinton ore and seems to indicate a replacement of limestone by iron bearing solutions as the origin of the upper ore.

SPECULAR HEMATITE OF THE PIEDMONT.

The specular hematite of the Piedmont occurs in Carroll County and extends from Sykesville to Finksburg. The ore is a vein deposit with quartz gangue, in a country rock of mica schists weathering to talcose and chloritic schists. The dip of the vein is nearly vertical, and its width varies from almost nothing to over fifteen feet.

To the south the iron occurs principally in the form of specular hematite; proceeding north, magnetite appears, and at Finksburg it is almost entirely magnetite. A sample of the ore taken from an outcrop of the vein at the Springfield Mine near Sykesville showed the following analysis:

ANALYSIS OF ORE FROM SPRINGFIELD MINE.

Fe	46.77
SiO_2	30.66
Al_2O_3	1.89
Mn	.18
P	.11
S	.05
Ignition	.43

In addition to the hematite and magnetite a small amount of chalcopyrite also occurs in the vein at the surface and the ore is frequently stained by copper minerals where it is weathered. With increasing depth the importance of the copper sulphide increases until the ore becomes a copper ore. At the Springfield Mine, the most southerly opening, the copper values exceeded the iron at a depth of about one hundred feet. To the north the copper becomes abundant near the surface, and at Finksburg practically extends up to the surface.

Several iron mines were opened on this vein but all of them soon became copper producers; and, on account of the small depth to which the iron extends the value of the deposit lies in its copper content.

THE MAGNETITES.

The magnetites of Maryland are confined to the Piedmont area and a strip along the border of the Piedmont and Appalachian areas at the eastern edge of the Blue Ridge Mountain. They occur in three distinct groups, the magnetites in the Loudon formation, those in the schistose rocks of the Piedmont, and those in the serpentines of the eastern Piedmont. Of these groups the Loudon magnetites are by far the most promising.

MAGNETITES IN THE LOUDON FORMATION.

The magnetites in the Loudon formation occur along the east edge of Catoctin Mountain in Frederick County. The first hill of Catoctin Mountain on the east is formed by an anticline of Weverton sandstone which overlies the Loudon formation. Six miles southwest of Thurmont the Weverton sandstone at the top of the hill has been cut through by erosion, exposing the underlying Loudon formation and the iron ore bed which it contains. At the foot of this small hill the Loudon formation is again brought to the surface by a sharp anticlinal fold pitching to the west, the eastern limb of which has been cut out by a fault running along the foot of the Mountain. Three miles northeast of Thurmont on the limb of this overthrust fold the magnetite bed again outcrops. These are the only known exposures of the ore; and, therefore, to determine the extent of the bed, a magnetic survey would be necessary. Since, however, it is a bedded deposit, it is extremely probable that the deposit is continuous between these points and extends for some distance beyond to the northeast and southwest, forming an extensive ore body.

The strata associated with the ore bed consist of dark blue shales carrying disseminated fine grained magnetite and some pyrite, the latter usually weathered to limonite. Between these

strata is a bed six feet thick which is richer in magnetite. The rock forming this bed is coarser than the shale and consists chiefly of grains of quartz and magnetite crystals, the latter also of larger size than those in the shales. A sample of the ore showed the following composition:

ANALYSIS OF LOUDON MAGNETITE.

Fe	35.02
SiO_2	33.82
Al_2O_3	9.43
CaO	1.04
MgO	1.50
Mn	.16
P	.04
S	.27
Ignition	1.98

In order to use these ores they would have to be concentrated. Mr. John Birkinbine in a report on the Catoctin property says:

An investigation made in 1896 showed that of the material claimed to represent the average of what could be economically mined, about one-third could be converted to concentrates. The size of the magnetic particles, however, is such that these would have to be briquetted at an additional cost. The analysis made of carefully separated ore indicates a satisfactory composition:

ANALYSIS OF LOUDON MAGNETITE CONCENTRATE.

Fe	65.20
SiO_2	6.25
P	.028
S	.038

Hence although trade conditions would hardly justify the working of this deposit at present, it must be looked upon as one of the important deposits of the State, and one that will furnish considerable ore in the future.

MAGNETITES IN THE SCHISTOSE ROCKS OF THE PIEDMONT.

The magnetites in the schistose rocks of the Piedmont occur in the sheared volcanics in southern Frederick County, and in the Wissahickon schists in Howard County near Hood's Mill

and in Harford County near Shawsville. These rocks throughout their extent frequently contain magnetite abundantly disseminated through them, and at a few points this has become sufficiently concentrated to give rise to an ore body of small extent. Several limonite deposits in these regions are probably the result of the weathering of such magnetite deposits.

MAGNETITES IN THE SERPENTINES.

The magnetites in the serpentines occur in the serpentine areas of northeastern Baltimore and northern Harford Counties. This region is an extensive area of Wissahickon schist into which the serpentine has been intruded and is now exposed in small lenticular patches. These serpentines were formerly important sources of chrome ore. In addition to the chrome, small deposits of magnetite have also been found. They are magmatic segregations occurring near the periphery of the serpentine masses. An analysis of a sample of this ore is given below.

ANALYSIS OF MAGNETITE IN SERPENTINE.

Fe	30.36
SiO_2	20.96
Al_2O_3	12.54
Mn	little
P	.06
S	.16
Ignition	5.54

These magnetites also all contain a small amount of titanium.

The deposits that have been worked were all of small extent and this type of magnetite deposits does not seem to attain any importance in Maryland.

SOME OBSERVATIONS ON THE TELLURIDES.

VICTOR LENHER.

INTRODUCTION.

In 1782, Müller von Reichenstein[1] in examining the Siebenburgen, Transylvania, gold minerals, which had been known as *Weissgolderz, Aurum paradoxicum, metallum vel aurum problematicum,* discovered the presence of a new metal similar in many respects to antimony and bismuth. Bergmann confirmed this discovery, but had too little material in hand to decide whether it was a new metal, or if it were antimony. In 1798 Klaproth[2] presented to the Academy of Science in Berlin a description of the new element which he named tellurium, and gave the first accurate differentiation of the element from antimony. Klaproth clearly showed this difference, and further showed the presence of the new element in the principal minerals of Transylvania.

The first accurate study of the properties of tellurium and its compounds was carried out by Berzelius,[3] who published two papers in 1834 in which he gave a systematic description of the chemistry of the element.

Thus far tellurium itself has found little application in the arts or industries. A use of potassium tellurate has been made on limited scale as a preventative of night sweats in consumptives. While the physiological action of tellurium derivatives resembles that of arsenical compounds, the general application for medical purposes will always meet with the objection in the fact that the introduction of tellurium compounds into the body, results in the production, from contact with tissue, of

[1] "Phys. Arb. eintracht. Freunde Wien," 3, 48, 1785.

[2] *Sitzber. Ak. Ber.*, Jan. 25, 1798. *Beitrage*, 3, I., 16, 20, 26, 1802. *Crell. Ann.*, I., 98, 1798. *Gilb. Ann.*, 12, 246.

[3] *Ann. de Chem. Phys.*, 2, 58, 113 and 225, 1835. *Pogg annal.*, 32, I., 577, 1834. *Kongliza Svenska Vetenskaps Akademiens Handlingar*, 1833, 227.

methyl telluride which possesses a very offensive and persistent garlic-like odor. In the patient this manifests itself in the characteristic "tellurium breath."

In metallurgy thus far no valuable properties have been found for the element or its alloys; indeed its general presence in alloys or in metals is objectionable rather than otherwise in that it tends to cause brittleness and diminished tensile strength.

OCCURRENCE.

Native tellurium occurs in the Transylvania gold deposit along with quartz, pyrite and gold. In like association it occurs in Boulder County, Col., and in the Cripple Creek District, Col. Selen-tellurium is a mixture of the two elments that frequently contains as high as 30 per cent. selenium. Tellurium is frequently associated in nature with gold, in fact the tellurium metals are generally gold bearing.

Calaverite, $AuTe_2$, sylvanite, $AuAgTe_4$, and krennerite, $(AuAg)Te_2$, are the best defined gold-bearing tellurides. Calverite is a silver white or slightly bronze colored mineral. It contains from 38.75 to 44.03 per cent. of gold and 0.90 to 3.52 per cent. silver. The formula $AuTe_2$ requires 43.59 per cent. gold and 56.41 per cent. tellurium. This mineral contains a higher percentage of gold than any other telluride. Its crystal form shows either monoclinic or triclinic symmetry. A detailed study of the crystal faces of calaverite has been made by Penfield and Ford[1] and they state that "The crystals seem almost to present a contradiction to some of the laws of crystallography."

Sylvanite, one of the most common tellurides of Colorado and Australia, is the mineral in which tellurium was first recognized by Müller von Reichenstein. It was named after Transylvania, in which country it was first discovered. The name sylvanium was one of the first to be proposed for the metal, tellurium. Its crystal form is monoclinic.

Krennerite is an orthorhombic telluride of white to bronze color. It is found at Nagyag in Transylvania, Cripple Creek,

[1] *Am. Jr. Sci.*, Sept., 1901, 225.

Col., and in the Great Boulder Reef in Australia. Its composition is variable, the mineral containing from 39.14 to 62.16 per cent. tellurium, 0.46 to 19.44 per cent. silver, 24.45 to 44.03 per cent. gold, with lead and antimony in varying proportions.

Of the tellurium minerals which are not so well defined or are not as plentiful, the number is large. Nagyagite was first found at Nagyag, Transylvania, but has since been found in the various tellurium districts such as Offenbanya, Hungary; Cripple Creek, Colorado; Kings Mountain Mine, North Carolina; Fredericksburg, Virginia; and on Tararu Creek, New Zealand. Kalgoorlite is a telluride of gold, silver and mercury. It is a dark-colored telluride which occurs in the Coolgardie gold field in Western Australia. Its exact mineralogical composition is uncertain. Coloradoite is a massive telluride of somewhat similar character to Kalgoorlite. Genth regarded Coloradoite as telluride of mercury, but by reason of its content of gold and silver it may be regarded as related to kalgoorlite. Hessite is a native isometric Ag_2Te, altaite is isometric PbTe, tetradymite is the rhombohedral telluride of bismuth Bi_2Te_3. Wehrlite and joseite are tellurides of bismuth which contain sulphur and selenium, melonite is the reddish white hexagonal telluride of nickel Ni_2Te_3. Stutzite is a rare telluride which approaches in composition Ag_4Te. Rickardite is Cu_4Te_3. Topalpite is a sulphotelluride of bismuth and silver.

In the oxidized form, tellurium occurs as tellurite or tellurium ochre. The mineral is the dioxide of tellurium. It is orthorhombic and has been found in the Transylvanian telluride deposits and in the Boulder County, Col., mines. The tellurites and tellurates which have been found are few in number and are closely related to telluride deposits. Like tellurium ochre they are probably incrusting oxidation products. Montanite, the tellurate of mercury, is considered by Genth to be a decomposition product of coloradoite. It has been found in the Magnolia District, Col. Durdenite and emmonsite are hydrated ferric tellurites. Ferrotellurite, another rare tellurite, is considered either to be ferric tellurite or tellurium oxide colored yellow by ferric oxide. The data regarding it are very meager.

The tellurium minerals from the earliest observations have been observed to be gold bearing. The districts in which they are found are all noted gold districts; indeed the gold mines of the Cripple Creek district and of Boulder County, Col., those of the Great Boulder Reef, Australia, and those of Transylvania depend largely on the tellurides for their precious metal values. These minerals contain gold so consistently that gold may be considered as a constant associate of tellurium minerals. In the Cripple Creek district and in Boulder County, Col., native tellurium is found. This tellurium always carries gold values, some of it like that of the Clarissa Tunnel in Boulder County runs as high as three per cent. in gold, while again the native tellurium will be found to be very low in gold.

The regularity with which gold accompanies tellurium and the tellurium minerals of whatever character is so consistent that when tellurium is found in any new locality, one of the first natural things is to have assays made for gold values. While this occurrence of gold with tellurium deposits has long been noted, it is not at all necessary that gold deposits should contain tellurium; in fact on the whole this association may be considered exceptional. The Mother lode of California in most places where the gold values are the highest are not tellurium bearing, and other instances of gold deposits which are tellurium free are too numerous for mention. Placer deposits are quite unlikely to contain tellurides on account of the brittle character of these minerals.

LABORATORY EXPERIMENTS ON THE TELLURIDES.

It has been the writer's good fortune at various times to study the different tellurium minerals in the laboratory from a chemical standpoint with the view to contributing, if possible, to the general knowledge of how they are deposited in nature. The general method of procedure in studying reactions of various kinds with minerals is to first make such preliminary studies with the available stronger reagents, and with much more violent reactions than would likely take place in nature. For the reactions which may properly be called rapid and violent in the

laboratory frequently give a clue to slow and less violent natural geological processes.

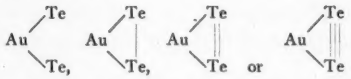
With this view in mind a series of systematic experiments have been conducted on the tellurium minerals and on their constituents with the hope that some light might be thrown on their deposition or on the chemical constitution of the minerals themselves.

The solution of the constitution of minerals is a problem of such difficulty that thus far little has been accomplished. The silicates have received a great deal of study through the valuable contributions of Clarke. Pyrite and marcasite have received a large amount of attention by Stokes. From time to time a large number of the minerals have been synthesized, yet but few of the experiments which have been made throw any light on the manner in which the constituents are combined. This is not so remarkable when we consider that our knowledge of the constitution of even the best known of the inorganic compounds is indeed very limited, and certainly incomparable with that of our knowledge of the organic compounds. The recent classical work of A. Werner, "Neuere Anschauungen auf dem Gebeite der anorganische Chemie," in which the constitution of a large field of inorganic derivatives is discussed, clearly illustrates the vast field of unsolved problems on the constitution of the well-known inorganic compounds.

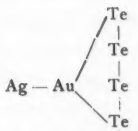
The methods which are available for the study of the constitution of chemical compounds in general may be said to consist in analysis, synthesis and various methods of decomposition.

A study of the tellurides reveals at once how difficult a subject this is to approach. Some of them, for example, the tellurides of lead, nickel, cobalt and silver preserve a tellurium-metal ratio corresponding to the valences of the respective elements expressed in their simplest form, while the gold tellurium minerals express ratios of valence which are not consistent with the ordinary valences of gold or tellurium. Tellurium shows the valence of two in its only hydride and the hydrides in general are usually taken as the parent substances to which binary compounds are referred. Gold forms derivatives in which it

shows the valences of one or three. None of the natural gold tellurides can be considered to show these simple valences. Calaverite has the composition $AuTe_2$ and if we attempt to make a graphic representation of its formula, we are likely to arrive at some such formula as



That of krennerite $(AuAg)Te_2$ would be practically identical, while that of sylvanite would have to show some such configuration as



in order to be consistent with the usually conceived valence of silver.

In the case of hessite the formula,

is thoroughly in keeping with our knowledge of silver and of what we should expect to be the formula of a body derived from hydrogen telluride which can be best represented by the formula

It is thus impossible to deduce from the empirical formula as derived from analysis of the minerals, any configuration which will throw light on the constitution of the minerals. On the other hand, the tellurides of other metals than gold seem to show the rational valence of tellurium and metal that are familiar in the common types of compounds.

Again, the methods which are available for the preparation of the tellurides of the metals other than gold are the conventional

methods which are used for the formation of sulphides. If, however, these methods are applied in attempting the formation of gold telluride, total failure in preparing a definite compound results.

A STUDY OF SOME REACTIONS OF TELLURIUM, SELENIUM, WITH SPECIAL REFERENCE TO THE TELLURIUM MINERALS.

Tellurium and Gold Solutions.—In 1828, N. W. Fischer (*Pogg. Annal.*, 12, 502) found that tellurium reduces the salts of gold, silver, platinum and palladium, when introduced into their solutions. He considered the reduction as incomplete in all cases, but that the reaction of gold solutions was the most rapid, the reaction in this case being stopped by the tellurium becoming coated with metallic gold which prevented further action even at high temperature. It has been found[1] that when metallic tellurium is treated with a chloride of gold solution, metallic gold is deposited according to the equation

$$4AuCl_3 + 3Te = 4Au + 3TeCl_4.$$

The reaction is greatly accelerated by warming the solution, and if the gold chloride is in excess and sufficient time is allowed, the tellurium completely passes into the solution leaving fine gold as a precipitate. On the other hand, if tellurium is introduced into a gold chloride solution in greater quantity than that necessary to precipitate all of the gold, the yellow gold solution will soon become completely bleached and on examination will be found to contain no gold. The action of the tellurium on the gold solution is fairly rapid; warming the solution a few minutes will bring down sufficient gold to color the tellurium yellow, but in order to insure a complete reaction two or three hours continuous heating are necessary or several days contact at room temperature. In order to obviate the difficulty of incomplete reduction noted by Fischer, it is only necessary to reduce the tellurium to a fine state of division and allow a sufficient time for reaction. When such conditions are fulfilled, the deposition

[1] Lenher, *Jr. Am. Chem. Soc.*, 24, 355.

of metallic gold by elementary tellurium is quantitative from either acid, neutral or alkaline solution.

Tellurium and Silver Solutions.—The reaction[1] between silver salts and elementary tellurium results in the formation of silver telluride. Silver nitrate solution in contact with elementary tellurium which has been reduced to a fine state of division will in eight or ten days yield silver telluride according to the equation

$$4AgNO_3 + 3Te = 2Ag_2Te + Te(NO_3)_4.$$

The reaction proceeds more rapidly if the solution is kept boiling or is maintained at a temperature of 80°. Silver chloride dissolved in ammonia will on contact with tellurium produce silver telluride, thus,

$$4AgCl + 3Te = 2Ag_2Te + TeCl_4.$$

In studying these reactions in ammoniacal solution, it has been observed that if silver nitrate dissolved in ammonia is allowed to stand for several days, or if the solution is kept warm for a considerable length of time, a black deposit which is probably a nitride of silver separates out. When silver chloride in ammonia is used in this reaction, an excess of ammonia is desirable, and the reaction is best carried out at room temperature. With silver nitrate in aqueous solution a greater range of temperature is possible, in fact the solution can be boiled continuously. The resultant precipitate, if extracted several times with ammonia, will lose any silver telluride held mechanically or formed in the reaction. With due regard to the above precautions it is possible to obtain a good preparation of silver telluride by the action of elementary tellurium on silver solutions.

Selenium and Gold Solutions.—Pure selenium acts with gold solutions in a manner similar to that of tellurium, the reaction being, however, very much moderated. The fused variety of selenium does not reduce gold at the ordinary temperature. Indeed one experiment was made allowing the selenium to remain in contact with the gold solution for three months without visible change. At the boiling temperature, the reaction proceeds nearly

[1] Hall and Lenher, *J. Am. Chem. Soc.*, 24, 918.

as rapidly as with tellurium, and takes place in a perfectly analogous manner, the reaction being expressed,

$$3Se + 4AuCl_3 = 3SeCl_4 + 4Au.$$

In order to secure complete action it is necessary that the selenium shall be in a fine state of division, and that sufficient time shall be allowed in order that complete contact may be assured. It is necessary for the solution of the gold to be boiled with the selenium for six to eight hours, or the gold solution should be allowed to be in contact with the selenium for two or three days at from 70° to 80°. The reaction then between selenium and gold solutions results in the quantitative precipitation of metallic gold.

Selenium and Silver Solutions.—Parkham[1] observed that red selenium is blackened in a solution of silver nitrate, selenious acid being formed at the same time; after the latter had been removed by sodium hydroxide, the black powder remaining contained selenium and silver, but no unchanged selenium could be detected with the microscope. Sendersens[2] found that selenium would reduce a boiling solution of silver nitrate, either dilute or concentrated, with the formation of silver selenide and selenium dioxide. The statement of Parkham is obviously in error in regard to a precipitate of selenium dioxide in aqueous solution inasmuch as selenium dioxide is readily soluble in water.

The action of selenium on silver solutions is quite similar to that of tellurium but is not as energetic. Selenium reduces solutions of silver nitrate or of the chloride in ammonia, either in the cold or on heating, with formation of silver selenide. As might be expected the reaction is materially accelerated by heat.

Reaction of Tellurium Minerals with Gold Solutions.—The tellurium gold minerals, calaverite, hessite, nagyagite, as well as native tellurium, all precipitate metallic gold from a solution of the chloride. In fact they deport themselves toward gold solutions precisely as elementary tellurium does. When the tellurium mineral is in excess the yellow gold solution is bleached

[1] *Chem. Cent.*, 33, 813.
[2] *Compt. rend.*, 104, 175.

to a colorless solution which contains no gold, while if the gold chloride is in excess, the amount of gold precipitated is in proportion to the quantity of tellurium and selenium present.

It is obvious that these natural tellurides act toward gold solutions unlike chemical compounds of gold and tellurium, since we know of no true chemical compound that can precipitate one of its constituents in such a manner as takes place with the natural tellurides and gold solutions.

Action of Various Reagents on the Tellurides.—It is possible to convert elementary tellurium into the tetrachloride by the action of sulphur monochloride.[1] Under similar circumstances, gold is not readily acted on. It is therefore possible to make use of this reagent with the tellurides. The entire series of gold tellurium minerals when treated with sulphur monochloride lose their tellurium content, leaving gold as a residue along with such silver as may be contained.

Such a reagent as nitric acid or hot sulphuric acid will liberate the gold, dissolving as nitrate or converting into sulphate the tellurium and silver.

At my suggestion, Dr. C. A. Tibbals, Jr., has made some experiments with the tellurides and certain oxidixing agents. Brauner[2] has shown that potassium permanganate and potassium bichromate, in either acid or alkaline solution oxidize tellurium dioxide to the trioxide. In view of these reactions and considering the general ease with which elementary tellurium oxidizes, Dr. Tibbals investigated the reactions of these oxidizing agents on tellurium itself, after which the natural tellurides were studied with the same reagents. Elementary tellurium when boiled for many hours with an alkaline solution of potassium permanganate is oxidized to tellurium dioxide or alkaline tellurite. The reaction proceeds slowly either with finely powdered fused tellurium or with the freshly precipitated element. The ratio of tellurium to potassium permanganate as shown in Dr. Tibbals's experiments corresponds to the equation:

$$3Te + 4KMnO_4 = 3TeO_2 + 4MnO_2 + 2K_2O.$$

[1] Lenher, *Jr. Amer. Chem. Soc.*, 24, 188.
[2] Brauner, *Jr. Chem. Soc.*, 59, 58, 238.

Brauner has found that tellurium dioxide in alkaline solution is readily oxidized to the trioxide by potassium permanganate at 60°, thus,

$$2KMnO_4 + 3TeO_2 = 3TeO_3 + 2MnO_2 + K_2O.$$

In the experiments of Dr. Tibbals it was shown, and Brauner has indicated, that boiling even for a few minutes decomposed the tellurate formed. The two oxidizing agents, permanganate and tellurate when boiled together yield oxygen and in turn go to manganese dioxide and tellurite.

Potassium bichromate of tenth normal strength acts very readily upon tellurium, oxidizing it in the cold, and will completely dissolve relatively large pieces of tellurium. It was found convenient to carry out the reaction in dilute sulphuric acid solution. The reaction proceeds thus:

$$Te + K_2Cr_2O_7 + 3H_2SO_4 = K_2TeO_4 + Cr_2(SO_4)_3 + 3H_2O.$$

Action of Permanganate on Tellurides.—Krennerite and permanganate. A weighed sample of selected krennerite from Cripple Creek was finely powdered and treated by Dr. Tibbals with a boiling alkaline solution of standardized potassium permanganate for fifteen hours. At the end of the time, the solution was cooled, acidulated, a weighed excess of ferrous ammonium sulphate was added and the amount of permanganate reduced by the krennerite measured by titrating the excess of the ferrous iron present with permanganate solution. The residue obtained by the action of the permanganate on the krennerite had the appearance of spongy gold.

It was weighed, fused with potassium nitrate to test for tellurium and reweighed. The two weights being identical showed that no tellurium was left in the gold residue, and that the action of the permanganate completely removed the tellurium from the mineral. The tellurium dissolved by the permanganate calculated from the equation,

$$3Te + 4KMnO_4 = 3TeO_2 + 4MnO_2 + 2K_2O$$

was 55.17 per cent., while the loss of the weight of the mineral

was 55.18 per cent. A quantitative analysis showed 55.18 per cent. The residue insoluble in permanganate after parting the gold and silver showed gold 38.28 per cent. and silver 6.54 per cent.

It is therefore evident that alkaline potassium permanganate completely removes tellurium from krennerite, leaving the gold and silver as a metallic residue.

Krennerite and Bichromate.—A finely ground specimen of Cripple Creek krennerite as was used in the previous experiment was treated by Dr. Tibbals with an excess of standard bichromate solution which had been acidulated with sulphuric acid and boiled for fifteen minutes, an insoluble residue of 43.24 per cent. of the original mineral was found which showed a content of 38.30 per cent. of gold and 4.94 per cent. of silver, but free from tellurium.

The observation has been made by Hendrixson[1] that fifth normal potassium dichromate with dilute sulphuric acid will dissolve metallic silver and this throws light on the low silver content found in the residue after treatment of krennerite with bichromate. The tellurium containing solution of the bichromate, when treated with a weighed excess of ferrous ammonium sulphate and the excess titrated with standard bichromate solution, gave a figure which when corrected for the silver dissolved showed complete solution of the tellurium in the mineral to tellurate.

Calaverite and Petzite with Permanganate and Bichromate.—The alkaline solution, as used by Dr. Tibbals, of potassium permanganate which was used with krennerite gave on long boiling a quantitative extraction of the tellurium while the gold and silver were left in the elementary form.

With a solution of bichromate, acid with sulphuric acid, both minerals were completely decomposed by a half hour's boiling, the tellurium and silver passing quantitatively into solution, leaving spongy gold.

Experiments conducted with these minerals diminishing the

[1] *Jr. Amer. Chem. Soc.*, 25, 637.

time of treatment with the boiling bichromate solution to ten and fifteen minutes showed a complete removal of the tellurium, but the silver was still retained in considerable quantity.

Experiments with Ferric Chloride.—When elementary tellurium is treated with ferric chloride[1] the tellurium dissolves, reducing the ferric chloride to the ferrous conditions thus:

$$4FeCl_3 + Te = TeCl_4 + 4FeCl_2.$$

This reaction has been studied by Pethybridge[2] who has made the reaction a basis for a patent for the extraction of tellurium from telluride gold ores. According to Pethybridge the ore is subjected in a fine state of division to the action of a solution of ferric chloride of a specific gravity of 1.18. The reaction will occur at any temperature, but the greater the degree of heat up to the boiling point of the solution, the more expeditiously will the process be carried out. The reaction between the solution of ferric chloride and sylvanite is represented as follows:

$$8FeCl_3 + (AuAg)Te_2 = 2TeCl_4 + 8FeCl_2 + (AuAg).$$

In studying this reaction with certain Cripple Creek ores it has been found that the extraction of the tellurium from a telluride ore is complete with the ferric chloride, but that in many instances notable amounts of gold dissolve. Mr. R. M. Chapman has studied this process carefully checking the procedure by many assays and has observed low gold results by this process.

BEHAVIOR OF VARIOUS TELLURIDES TO HEAT.

It is a well known fact that the telluride ores when roasted in the air lose all of the tellurium contained. The ores or minerals when fused with oxidizing mixtures such as saltpeter lose their tellurium completely. Further, when the tellurides are heated in hydrogen gas the tellurium gradually distills, leaving a metallic residue free from tellurium.

[1] Lenher, *Jr. Am. Chem. Soc.*, 30, 744.
[2] U. S. Patent No. 709,037, Sept. 16, 1902.

PETZITE HEATED IN CARBON DIOXIDE.

It was suggested to Dr. Tibbals to study the action of various gases on the tellurium minerals.

A sample of finely powdered petzite from Boulder County, Col., was accurately weighed in a porcelain boat and heated in a porcelain tube in an atmosphere of dried carbon dioxide. The weight of the boat and contents became constant after twenty-four hours. The petzite lost 35.07 per cent. of its weight, the residue consisting of gold and silver free from tellurium. The particles of silver in the boat were fused together after the experiment while the gold appeared in part as a yellow incrustation on the surface of the silver, resembling the appearance shown when a telluride mineral is roasted in the air. The temperature during the experiment was not sufficiently high to cause the silver and gold to fuse together.

Tellurides Heated in Hydrochloric Acid Gas.—A portion of the Boulder County, Col., petzite was heated in a glass combustion tube to a low red heat for twenty hours in a current of hydrochloric acid gas. Before heat was applied to the tube all of the air was expelled from the apparatus by hydrochloric acid gas. When the mineral was heated to redness, the tellurium began to volatilize and condensed on the walls of the tube as a black mirror. The residue remaining in the boat consisted of fused silver chloride with particles of metallic gold. The ammoniacal solution of this residue when treated with nitric acid gave the silver chloride as a precipitate.

It is thus seen that when dry hydrochloric acid gas is passed over heated petzite, the silver is converted into chloride, leaving the gold in the free condition, while the tellurium is volatilized and condenses in the elementary form. Artificial silver telluride prepared by the reduction of a silver telluride in hydrogen deported itself in the same manner as the mineral, with the result that in this instance both metallic tellurium and tellurium tetrachloride were deposited on the walls of the tube, while the silver was completely converted into silver chloride.

Artificial gold sulphide Au_2S_3 prepared by the action of

hydrogen sulphide on an auric chloride solution was heated in hydrochloric acid gas. The sulphur began to volatilize below redness and deposited on the tube, leaving metallic gold in the boat.

Krennerite subjected to the same treatment with hydrochloric acid gas lost all of its tellurium, leaving a residue of metallic gold and silver chloride.

Treatment of Petzite and Krennerite with Sodium Sulphide.—Finely ground samples of petzite and krennerite were sealed by Dr. Tibbals in glass tubes with strong solutions of sodium sulphide and the tubes were heated for two weeks at 50°. At the end of the time the minerals were found to be unchanged.

Fresh samples of the minerals were heated for twenty-four hours in sealed tubes at 200°. In this experiment the petzite was found to be unchanged, but the krennerite was acted on by the reagent. At the end of the experiment, the krennerite was found to be covered with a coating of metallic gold. The sodium sulphide solution was found to contain tellurium.

ATTEMPTS TO PREPARE ARTIFICIAL TELLURIDE OF GOLD.

When gold is mixed with tellurium and the whole heated a white crystalline alloy is obtained. Brauner[1] in an elaborate paper on the atomic weight of tellurium attempted to synthesize a number of metallic tellurides, among others telluride of gold. He obtained crystalline polytellurides of a silvery luster, but they were not of definite composition. The fusions obtained by Brauner were alloys of gold and tellurium. The nearest approach to a definite formula was Au_2Te. Recently the alloys of gold and tellurium have been studied by Rose[2] who has established a complete freezing point curve with various concentrations of tellurium and gold. The curve indicates one compound $AuTe_2$ melting at 452°. Eutectic mixtures were formed with gold and tellurium of the composition $AuTe_6$ and AuTe, but they do not show the characteristic banded eutectic structure. There are no certain indications that they are true compounds.

[1] *Jr. Chem. Soc.*, 55, 391.
[2] *Trans. Inst. Min. Metal Brit.*, 17, 285.

By the examination of fused mixtures of gold and tellurium no evidence was obtained of the existence of compounds corresponding to the minerals petzite, coolgardite or kalgoorlite.

The experiments of heating gold and tellurium in inert or reducing gases have been repeated. When a mixture of gold and tellurium, the latter being in great excess, is heated to redness in a current of either hydrogen or carbon dioxide, the tellurium gradually distills from the boat, leaving pure gold as a final residue. Should the length of time of heating be insufficient to drive off all of the tellurium, a crystalline silver white mass will remain behind. If this is again heated, it will become golden colored on the surface, gradually losing more and more tellurium until the remaining gold is tellurium free. If any of the white alloy-like substances obtained as intermediate products by heating gold with excess of tellurium and the final product of pure gold are treated with gold chloride solution, the gold chloride is reduced to metallic gold. This reaction of gold chloride on the artificial alloy of gold and tellurium is precisely the same as its action on the telluride minerals. If the telluride of gold is a salt of hydrogen telluride in the sense that many of the natural sulphides may be considered as derivatives of hydrogen sulphide, it would seem as though it would be formed by the action of hydrogen telluride gas on a gold solution, or by the interaction of a gold solution on a soluble telluride. In order to test this view various experiments have been conducted.

Hydrogen telluride gas prepared by the action of dilute hydrochloric acid on aluminum telluride was brought in contact with gold chloride solutions. Should it be possible to form a telluride by this method of procedure, the hydrogen telluride would of necessity have to be in excess; otherwise the precipitated telluride in contact with the excess of gold salt would be transformed into metallic gold by the action of the gold telluride on the gold chloride. Such is actually the case, when hydrogen telluride is conducted into a gold chloride solution, the gas being only sufficient in amount to precipitate a small portion of the gold in solution, pure metallic gold is precipitated and this gold on careful examination proves to be free from tellurium. When

the hydrogen telluride in excess is conducted into the gold solution, metallic gold is also thrown down free from tellurium, the procedure of the reaction evidently being in the direction of a reducing action, rather than that of the formation of a telluride. The reaction may be expressed:

$$2AuCl_3 + H_2Te = 2Au + TeCl_4 + 2HCl.$$

According to these experiments, hydrogen telluride does not form telluride of gold in the wet way.

In a general study of the metallic tellurides, Tibbals[1] has prepared a large number of the tellurides of the metals by bringing a solution of a metallic salt in contact with a solution of sodium telluride. The experiments were carried out in an atmosphere of hydrogen, from which all air had been rigorously excluded in order to preclude the decomposition of the alkaline telluride, which on air contact oxidized with separation of elementary tellurium. While this method of procedure enables us to precipitate the pure tellurides, silver telluride Ag_2Te, zinc telluride ZnTe, cadmium telluride CdTe, when brought into contact with the appropriate solutions of their corresponding salts, the reaction toward gold solutions is entirely different. The action of sodium telluride on gold solutions results in the precipitation of metallic gold which is free from tellurium. The reaction may be assumed to proceed,

$$2AuCl_3 + Na_2Te = 2NaCl + TeCl_4 + 2Au.$$

In a separate study Dr. Tibbals investigated the action of sodium telluride solutions on solutions of sodium sulphaurate. The sodium tellurite was prepared by reduction to the telluride with sugar carbon at a red heat in a temperature of hydrogen. The solution of sodium sulphaurate was obtained by dissolving auric sulphide in sodium sulphide at 10°. The solutions were of necessity kept in an atmosphere of hydrogen and the experiments were conducted in hydrogen. In a series of ten experiments performed under approximately the same conditions precipitates

[1] *Bulletin University of Wisconsin*, No. 274, 1909.

were obtained when the sodium telluride was in excess, which contained all the way from 23.35 per cent. to 54.33 per cent. of gold, but no two were of the same composition or of rational formula. Under more widely differing conditions no telluride of gold of rational formula or of constant composition is formed. Inasmuch as the natural gold tellurides are so frequently associated with calcium compounds, calcium telluride suggested itself as a means of precipitating or transporting tellurium or gold. When, after great difficulty, a calcium telluride was finally prepared in pure condition, it was found to be readily decomposed by water into calcium hydroxide, tellurium and hydrogen, hence was not available for experimentation.

COPRECIPITATION OF GOLD AND TELLURIUM.

Various methods have been tried at different times to precipitate gold and tellurium together from widely different kinds of solutions and with various reducing agents, the result invariably has been that the gold precipitates first. This is obvious inasmuch as even though any tellurium should come down at first, on coming in contact with the gold in solution it would have precipitated the latter. The precipitates, therefore, which are obtained by this method are non-homogeneous mixtures of gold and tellurium.

TRANSPORTATION OF GOLD AND TELLURIUM BY NATURAL SOLUTIONS.

The transportation of gold-bearing solutions has been discussed at length by Van Hise in his treatise on "Metamorphism" and by Clarke in "The Data of Geo-Chemistry." In both of these valuable and suggestive works the views of those who have studied the solubility of gold and its transportation have been carefully reviewed as well as discussed. The general tendency is to attribute the transportation of gold to a chloride solution. This would seem to be the more natural means for the gold to be transported in view of the relative stability of gold chloride when compared with such other salts as the sulphate, nitrate, phosphate, the aurates and sulphaurates.

Metallic gold can be dissolved and held in solution by a great variety of solvents. While *aqua regia* or free chlorine are the most common solvents and undoubtedly the best for free gold, the production of free chlorine in nature is not a phenomenon to be expected on an elaborate scale. The well-known solvent, potassium cyanide in presence of air is another laboratory reaction that could hardly be expected to be of serious moment as a natural geological process. That many other reagents attack gold is also known and it is striking that many of these solvents are substances which can readily be formed in natural process. It was our opportunity to test many of the previous observations of others in the laboratory, and it is felt that gold can be rendered much more soluble than is commonly supposed if sufficient pressure is brought to bear during the reaction. Thus it has been observed that while boiling concentrated hydrochloric acid is without appreciable action on gold, under pressure the gold will dissolve with comparative ease. The presence of such alkaline chlorides as sodium, potassium or ammonium chloride in solution with hydrochloric acid will cause gold leaf to pass into solution when heated in a sealed tube under pressure. Aqueous solutions of the above mentioned alkaline chlorides act in a similar manner when heated with gold leaf under pressure even in absence of hydrochloric acid. The pressures obtained in these experiments were all below 100 pounds square inch, the temperature rarely rising as high as 165° C. The action of ferric chloride and cupric chloride has been shown by Stokes to be reversible, solution of the gold being effected at 200° C., while on cooling the gold is redeposited. Solutions of alkaline sulphides have been known for a long time to act as solvents for gold. Concentrated sulphuric acid or strong phosphoric acid at temperatures up to 250° C. have apparently no solvent action on gold, although in the presence of oxidizing agents either of these acids will dissolve gold at atmospheric pressure. The alkaline solutions employed such as the alkaline silicates or carbonates have given only uncertain results when heated under pressure with gold leaf. These solutions are able, however, to

hold the gold in solution if gold is heated with these alkaline solutions containing alkaline chlorides.

In whatever form the gold is transported in solution whenever it comes in contact with tellurium or a telluride deposit, reduction ensues and metallic gold is thrown out of solution. This serves to explain the existence of metallic gold in the upper portions of the telluride mines, and the deposition of gold from solution by the telluride minerals, and also explains the pseudomorphs which are so common of gold after the telluride minerals and the not infrequent coatings or incrustations of gold on the surface of the tellurides.

As Van Hise has pointed out in his "Treatise on Metamorphism," it would seem to the author that it is possible that the gold in its journey as chloride meets a tellurium-bearing solution, and on contact with reducing compounds in solution or in contact with such reducing solids as sulphides, the two are simultaneously reduced under such conditions that they are able to produce the telluride minerals.

The gold and tellurium solutions as chlorides can travel together or independently as long as they do not come in contact with a reducing agent.

Tellurium can be transported in nature in a number of ways. The alkaline tellurites or tellurates, or their corresponding acids in the free condition, tellurous or telluric acids are readily soluble and could serve as either an acid, neutral or alkaline solution of transportation. Tellurium as sulphide is readily soluble in the alkaline sulphides, and so long as free oxygen is absent, there is no reason why tellurium cannot be transported in alkaline sulphide solution. The close association of the tellurides with more deep seated sulphides would suggest that it is possible that these sulphides furnish sulphide solutions which are capable of carrying the tellurium, and that on contact with the gold solutions from lateral sources they are able to produce the telluride deposits. The association of antimony with tellurides in the Transylvanian minerals and of the continual presence of antimony along with tellurium in the Montana Copper ores would indicate a deposition from sulphide solution. It would also seem possible that the

alkaline sulphide solutions of gold and tellurium on coming into a zone of oxidation would cause deposition of the tellurium and gold simultaneously and thus produce the telluride minerals. Actual observation however shows that the occurrence of the tellurides is largely in the zone of reduction. While it is possible for either gold or tellurium to be transported in alkaline sulphide solution, it is not possible for silver to be transported by means of an alkaline sulphide, due to the insolubility of silver sulphide. Silver chloride is, however, soluble to a considerable degree in the alkaline chlorides and can thus be carried in nature. The telluride of silver can be readily formed as has been shown in the experiments cited, by contact of silver solutions with metallic tellurium, by reduction of the tellurite or by the action of hydrogen telluride or an alkaline telluride on a silver salt. Actual observation has shown, however, that pure silver telluride is rare.

The deposition of the more common mixed gold and silver tellurides, in light of our present knowledge, would appear to be more likely from the intermingling of a solution of gold and silver chlorides held in solution by an alkaline chloride with an alkaline sulphide solution carrying tellurium.

From the experimental evidence at hand, it would seem that the tellurium gold minerals partake more of the nature of alloys than of chemical compounds.

The manner in which the gold and tellurium are united is an unusually difficult problem to approach, and thus far little of definite character, so far as the constitution of these minerals are concerned, has been established. The experimental data which is available all seems to point to the nonexistence of a definite artificial telluride, the artificial products being largely of the nature of alloys and in general character resembling the telluride minerals.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

STUDIES IN THE APPLICATION OF THE ANTICLINAL THEORY OF OIL AND GAS ACCUMULATION.

DISCUSSION OF A PAPER BY M. J. MUNN IN ECONOMIC GEOLOGY, MARCH, 1909.

Sir:—As the "Application of the Anticlinal Theory of Oil and Gas Accumulation," by M. J. Munn, in the March number of ECONOMIC GEOLOGY, is a subject to which I have given some thought, and as I am familiar with many pools in western Pennsylvania, eastern Ohio and northern West Virginia, where the formations he describes are productive or have been penetrated by the drill, I wish to accept the author's invitation to discuss the hypotheses in question.

The term "anticlinal theory" is an unfortunate one in some respects, as it gives a non-geologist the idea that the adherents to this theory believe the distribution of oil and gas pools to be dependent on anticlinal structure and on nothing else. Such is not true, however. Personally, I have found it necessary scores of times, when questioned by well drillers or operators as to whether I believed in the "anticlinal theory," to qualify my affirmative replies by informing them that the theory holds as an important factor in the accumulation of oil and gas, even in pools in which no definite relation to geologic structure is apparent, and in regions where there are no definite anticlinal or

synclinal axes. I have further found it necessary to qualify my replies by explaining that the structure of the rocks, and consequently the "anticlinal theory," is only *one* of the factors in the accumulation of oil and gas pools, and that a geologist, in order to locate a pool, even approximately, has to consider every other particle of evidence found in structure of the subsurface rocks, changes in intervals, texture of the "sands," character of the overlying beds, differences in pressure, relations to water in the rocks, shape of the surrounding pools, and character of the oil in the vicinity; and every factor must be given its due weight, before a recommendation can safely be made. After all other factors have been considered, it might seem as if the "anticlinal theory" had been lost sight of as unimportant; yet the fact remains that structure is the essential condition which finally determines the distribution and size of the pools when all other conditions are favorable.

Mr. Munn's paper is an admirable one, but some statements appear with which I cannot agree. The Hundred-foot sand, described by him, in the Sewickley quadrangle, underlies "thousands of square miles in western Pennsylvania and Ohio." It also extends southward into West Virginia. In southwestern Pennsylvania and in West Virginia it is broken up into the Gantz sand and the Fifty-foot sand, separated by a bed of shale. Both these sands may be productive of oil in a single well. Everywhere throughout the area in which the Hundred-foot sand, or its constituents, produces oil, it consists of a well-defined sandy group occurring at what is supposed to be the very bottom of the Carboniferous system. Directly below the Hundred-foot, or the Fifty-foot sand, are found the Catskill red shales, which are easily recognized by the drillers.

Scores of pools have produced, and are producing, oil from the Hundred-foot sand, but many times as many are producing from other sands, lying below and above the Hundred-foot. Whatever conditions affect the accumulations of oil in one sand must be factors of greater or less importance in all of them; but the differences in character of the sand and other rocks, and the oil, gas and water existing at different places in them, fre-

quently produce structural relations which might appear, at first thought, to be entirely contrary to conditions in other pools with which the operator may be familiar. The Berea, or Thirty-foot, sand, lying at an average distance of 150 feet above the Hundred-foot, is of much wider extent as a productive sand than is the Hundred-foot.

The Hundred-foot sand is the chief productive horizon in the Sewickley quadrangle, and is also productive a few miles west, in the eastern part of the Beaver quadrangle. In the western and northern parts of the Beaver quadrangle the Berea sand is productive, and the Hundred-foot, though present, has not yet been found to contain oil, although many holes have been drilled to it.

The oil pools in the Beaver quadrangle, and in the quadrangles north and west of it, occur in thin "pay-streaks," as in the Sewickley quadrangle, and certain features, including the general character and distribution of the "pay-streaks," agree with those described by Mr. Munn. As found elsewhere, there are some dry areas several miles in extent, which lie directly down-dip from important pools of oil or of salt water or of both. For instance, near the corner of Brighton, Chippewa and South Beaver townships, in Beaver County, is a small pool in which the production of the wells is so light that they are not worth pumping, producing at best only a barrel or two a day. This pool is bordered on the northeast, southeast and south by a number of strong salt water wells. Contrary to the expectation of the operators, this pool was not found to lead to a stronger one near by, the dips of the rocks being too gentle to form any strong accumulation. The "pay" here, as in most pools of the Berea sand, is near the top of the sand. The salt water in close proximity to the pool occupies a definite structural position with reference to it, occurring on all sides of the pool except on the up-dip side. However, this water was not found to extend far southeast of the pool, several wells between there and Ohio River, four miles southeast, having been dry of water and oil. Similar occurrences are found repeatedly in the Berea sand in the Beaver and Newcastle quadrangles in Pennsylvania

and in the Steubenville and Wellsville quadrangles in West Virginia and Ohio, where dry sands occur on the down-dip sides of pools of oil and of salt water.

I can not agree with Mr. Munn that "the evidence as a whole is decidedly against the idea that the pools could have been accumulated by difference in gravity of oil and salt water." Everywhere, within a particular pool, where gas, oil and salt water are present, the gas occurs *above* the oil, and everywhere the main pool of salt water occurs *below* the oil, not directly underneath, but at right angles or at an acute angle down-dip. Although "lateral movement through difference in gravity alone," may, during historical time, have been "so limited as to be of no consequence," I have been obliged to dismiss all assumptions of the oil having been accumulated without regard to structure, and consequently gravity.

A point to be noted in pools a short distance west of those described by Mr. Munn is that the lowest oil pool in the Berea sand in a given group of pools is successively higher above sea-level going from southwest to northeast parallel with the Ohio River. Near Steubenville and Mingo, in Jefferson County, Ohio, the lowermost elevation of the oil yet discovered in this sand is 600 feet below sea-level; at Holliday's Cove, West Virginia, it is about 400 feet below sea-level; on the West Virginia-Pennsylvania line near the southwestern corner of Beaver County it is 250 feet below; at Hookstown and Smiths Ferry, Beaver County, it is at sea-level; while near the corner of Brighton, Chippewa and South Beaver townships it is 200 feet *above* sea-level. This progressive rise is not explained by Mr. Munn's theory, but it is explained in part by the greater general height of the anticlinal folds and the lesser depth of the adjacent synclinal depressions toward the northeast.

At the time the oil sands and intervening strata were deposited as sediments in the sea, the pores of all sandstones and other porous rocks must have been saturated with salt water. Through some cause, most of the water seems to have dissappeared, leaving only scattering pools of it still present. We may fairly question, however, whether the harder and closer-grained por-

tions of the Berea and Hundred-foot sands, where they are reported by drillers as dry, are in reality as dry as the appear to be, or whether they seem so owing to their lack of porosity. The fact that the still deeper oil sands, below the Hundred-foot, yield troublesome water much less frequently than do the upper ones, that they require no casing, and that the drillers seldom report water from them, indicates that most parts of these sands, whatever their texture, are really dry, and this view is in accord with the best data in deep mines, *i. e.,* that rocks below 1,000 feet or so are commonly dry of water. Whatever the cause of the real or apparent dryness of portions of the upper sands, the salt water, accompanied by whatever oil may have been present in any beds, was concentrated by rock pressure, molecular attraction, seepage, hydraulic pressure and other causes, and accumulated to a great extent in the more porous portions of the sandstones (in the "pays"). In deeply-buried sands the pressure alone would account for the segregation of the oil and salt water in the "pay-streaks."

Most of the "pays" in which the oil and salt water are found are many miles in extent, and the accumulations could not have been sufficient for economic development at any particular point in a sand or "pay," were it not that the rocks were subsequently tilted. The truth of this statement is manifested particularly by an area covering large portions of several counties fronting on Ohio River is southwestern West Virginia, in which conditions are otherwise favorable, where the dips are so slight that only shows of oil and gas have been obtained by drilling. Where the oil was concentrated into pools it was assisted by tilting of the rocks, which gave a partial or entire anticlinal structure. In each individual porous lentil, or "pay-streak," the oil, water and gas occupying it and the closer-grained rock in proximity to it, were arranged according to their specific gravities at the lowest point on the down-dip side of the "pay-streak." The deposits could not be arranged in any other way. The fact that a so-called "pay-streak" lying down-dip from a known pool may be dry of both water and oil does not disprove the anticlinal theory in its proper application; but its position is due to the

fact that whatever water and oil may once have occupied the "pay-streak" have been drained out or segregated elsewhere, naturally or artificially, or that the streak is not in reality so porous as would seem from the size of grains in the sand-pumpings. The arrangement of the grains, and the proportions of different relative sizes, are more important in determining a "pay" than is their absolute size.

FREDERICK G. CLAPP.

REVIEWS

Fluorspar Deposits of Kentucky. By F. JULIUS FOHS. Kentucky Geological Survey, Bull. No. 9, 296 pages.

This bulletin, which bears the date of 1907, was considerably delayed in publication, but finally made its appearance near the close of 1908. It is probably the most important contribution to the literature of fluorspar that has been published in the United States. Besides a description of the fluorspar district of Kentucky, with details regarding mines and mills, a summary of the progress of the fluorspar industry in Kentucky and in the United States is given for 1905–6, together with much historical and statistical information, as well as an analysis of trade conditions. With regard to trade conditions, an important section of the discussion relates to materials that compete with American fluorspar, such as limestone flux, imported fluorspar, and cryolite and its products. The mineralogy and geological associations of fluorspar are described in some detail and a list of producing localities in the United States is given. With regard to the Colorado deposits, the author has evidently had incorrect information, since he states that certain deposits which are still producing are reported to be worked out. This chapter, however, should be of especial value to the student for reference work on the mineralogy of fluorspar.

In regard to the exploitation of local deposits, the chapter on prospecting and mining methods will be of especial value to the mining man who is interested in the Kentucky field. The chapter on milling methods is not only of local interest but of value to producers of fluorspar in the West, where no methods of cleaning and concentrating spar are in use. This chapter gives descriptions of log and gravity washers, screens, crushing, concentrating, and grinding apparatus, and describes in detail several mills in Kentucky and Illinois. Several instructive half-tone illustrations accompany this chapter. An important feature of the chapter is a discussion of the problems relating to ore dressing and to special separation processes since upon the recognition of the principles involved depends the selection of machinery best adapted to the needs of each case.

Thirty-two pages are devoted to a discussion of the uses and technology of fluorspar. A large variety of uses of spar have been recorded here, each dependent upon certain properties of the mineral,

and the suggestions should be of great value in establishing new markets and in expanding old ones. Interesting details are given with regard to the manufacture of hydrofluoric acid; with regard to fluorspar in metallurgy of iron and steel, aluminum, manganese, silver, copper, tin, nickel and zinc; with regard to the production of alundum, the manufacture of glass enamels, glazes and fireproof ware, and the production of apochromatic lenses, carbon electrodes for the flaming arc; and with regard to the use of fluorspar for ornamental purposes. One chapter that would be of use to chemists who desire to work on fluorspar is that treating of the methods of analysis of fluorspar compounds. A summary that will doubtless be of temporary local interest is a tabulated list of mines, mills, and operators in the Kentucky fluorspar district.

Besides the data strictly relating to fluorspar there is mention of lead and zinc in association with the spar and a few pages are devoted to the occurrence of cobalt and nickel in western Kentucky. There is also given a useful compilation of simple tests for common minerals which the prospector may find in the fluorspar and metalliferous districts in Kentucky and elsewhere.

With regard to statistics of fluorspar production collected by organizations other than the Kentucky Geological Survey, including other State Surveys, the U. S. Census Bureau, and the U. S. Geological Survey, the author does not hesitate to brand nearly all as inaccurate in some particulars. The intense state partisanship which seems to pervade the bulletin in all matters relating to competition in the fluorspar industry might perhaps better have been subordinated. For instance, on page 10, the statement is made that Illinois fluorspar operators undoubtedly supplied excessive returns to both the U. S. Geological Survey and the *Engineering and Mining Journal* for 1905, since they showed production and shipments *double* the real ones for that year. This statement is not accompanied by any facts in its support. Mr. Fohs, however, personally looked carefully into the industry in both Kentucky and Illinois and he should naturally be expected to be the best informed authority on this point. On page 11 it is stated that an advantage in freight rates of $1.00 per ton is given Illinois shippers and that rebates are reported as being given to Illinois shippers. It is difficult to understand how or why rebates, as well as an enormous advantage in freight rates, should be given the shippers of fluorspar in one state over those of an adjacent county in an adjoining state, especially when the same railroad carries the product of both districts. Unfortunately no figures or rates are given in support of this statement. On page 19, in the discussion of imported fluorspar as a competitor of the American product, it is stated that one reason for the

advantage English fluorspar has had in the Pittsburg markets is the low freight rates granted the product from seaboard to Pittsburg, the published rate for which is $2.60. Furthermore, it is stated that through rebates granted to English shippers the freight cost has been only $1.60 per ton. If the published rate of $2.60 has really been rebated to $1.60 this is a serious matter and is worthy of investigation, but to dignify by publication in a state report, without having probed the matter to the bottom, such a statement as this that may be mere gossip seems somewhat inconsiderate.

The bulletin is printed on good paper with large clear readable type, and good illustrations. The compositor has fallen into the error of spelling fluorspar "flourspar" in many instances, and it is surprising that such an aggravating error should have passed unnoticed by the proof readers.

The permanent value of this bulletin will rest in (*a*) the scientific matter relating to the general mineralogy and geological association of fluorspar, a compilation which has required the expenditure of much time and effort; (*b*) the data furnished regarding the geologic relations of the Kentucky deposits and the methods of mining, milling and using the spar. The bulletin is certainly very welcome to all who are interested in the fluorspar industry. Mr. Fohs and the Kentucky Geological Survey are to be congratulated on having put forth, as Dr. Norwood, Director of the Kentucky Geological Survey, styles it "The most complete publication on fluorspar that has ever been issued."

ERNEST F. BURCHARD.

Second Report on the Clay Deposits of Georgia. By OTTO VEATCH, Assistant State Geologist, State Geological Survey of Georgia. Bulletin 18, p. 453, Pl. XXXII., Fig. 15, Maps 3. Atlanta, 1909.

The first report on a part of the clays of Georgia concerned only the clays along the Fall Line, but the second includes all the clays in the state. The clays in the second report are, for convenience, grouped according to their occurrence in each of the three geologic and physiographic divisions of the state, namely, the Paleozoic area, the Crystalline belt, and the Coastal Plain.

The Cretaceous clays, known as the Fall Line belt of white clays, are confined mainly to the Tuscaloosa (Potomac) formation, which forms the northern margin of the Coastal Plain. The clays occur as pockets or lens-shaped beds of comparatively small extent enclosed by sand, or as horizontal beds lying in contact with later sands and clays. The deposits are from one to thirty-five feet in thickness, and from a hundred yards to several miles in extent. The purest clays occur between Macon and Augusta, in a belt approximately 110 miles long and 3 to 15 miles wide.

Since kaolin is usually a residual clay, the author has outlined with some care, a theory to account for the sedimentary origin of these clays.[1] The theory, briefly, is that following the uplift of the piedmont region that occurred just before Cretaceous time, the residual kaolin from that region was washed downward and deposited by a natural process of separation in offshore fresh water lakes and sounds which had been enclosed by torrential movement of coarse sediments.

These white clays are often remarkably close in chemical composition to kaolinite, one sample showing 99.16 per cent. clay substance. In texture the clays are very fine grained, although they may contain rather coarse sand. The sieve tests on some of the samples show 95 per cent. passing a 200-mesh screen. In hardness the clays vary from soft and cheese-like to flint clay. All except the flint clays develop good plasticity. Under the microscope free silica appeared in the soft clay, usually as angular or subangular quartz particles, often coated with iron oxide, and in the flint clays as opaline silica, which is doubtless the cementing agent in these clays. No kaolinite crystals were detected. The drying shrinkage of the clays is moderate, but the burning shrinkage is high. In the purest clays this amounts to from 10 to 15 per cent. at cone 9, where it practically ceases. The purer clays vitrify above cone 15 and fuse above cone 33.

The clays are now being used in the manufacture of white ware, electrical porcelain, etc., fine brick and other refractories, and terra cotta. In the raw state they are used as filler for wood pulp paper.

The Tertiary deposits of white clays are not as extensive nor as pure as those of the Cretaceous, and it is doubtful whether any of them are of value for the manufacture of high grade products, but some of the clays are refractory and occur in large quantities, and may be of future economic importance.

The Paleozoic clays consist of sedimentary clays associated with coals, residual deposits derived chiefly from the decay of limestones, and clays associated with certain deposits of iron ore and with bauxite. The last named are the most important, and although not in present use, are certain to become commercially valuable. These clays occur with the bauxites, and, in fact, enclose them, so that the latter cannot be mined without moving large quantities of clay. This clay contains a higher percentage of alumina than is found in kaolins, and is consequently highly refractory. In laboratory tests the clay remained unfused at cone 36.

In connection with the discussion of these clays, the author makes the interesting deduction that since the best theory of the origin of the Alabama and Georgia bauxites is that they are chemical precipitates,

[1] See ECONOMIC GEOLOGY, Vol. III., No. 2, pages 109–117.

and that field study gives no evidence that the clays are not contemporaneous with the bauxite, it is probable that the clays are chemical deposits.

EDWIN F. LINES.

URBANA, ILL.

Report on the Examination of Some Iron Ore Deposits in the Districts of Thunder Bay and Rainy River, Province of Ontario. By F. HILLE, M.E. Canada Department of Mines, 1908.

In his report on the iron deposits of the Rainy river and Thunder bay districts of Canada, Mr. Hille foresees a not far off time, when Canadian iron deposits will not only succeed in meeting the domestic demand, but that of the entire world. This titanic revolution in the industry of iron and steel, Mr. Hille believes will result from the failure to discover new deposits of importance, and the rapid exhaustion of available deposits in the United States. In his own words, "Whence then can the deficiency be made up? The only possible source that I can see is Canada." . . . "If an estimate were made of what is already known of the iron ore reserves throughout the Dominion, there can be little doubt that Canada would stand high, if not first among the nations of the world as a prospective producer of iron." While giving no numerical estimate of the iron resources of his own country, Mr. Hille estimates the iron reserves of the United States to be no more than from 5,000,000,000 to 10,000,000,000 tons, which he says will be exhausted in 1940, at the rate of increase of consumption during the past 25 years. The reserves of other countries are regarded by him as almost negligible, partly for political reasons, in the problem of future availability Mr. Hille's confident estimate of the iron reserves of the United States is vastly less than that given by the United States Conservation Commission.

The Canadian iron deposits which Mr. Hille regards as especially promising are those of the Matawin, Atikokan and Animikie districts. The economic exploitation of the lean, siliceous magnetic iron deposits of the Matawin district can be accomplished according to Mr. Hille, by (1) hydromagnetic separation of the ores, (2) smelting the ores at or near the mines, (3) securing the furnace materials, coke and flux, from sources near the mines, (4) utilizing the by-products of the coke industry, (5) using the local water power of the streams for driving machinery and conducting metallurgical operations. In the peat bogs and forests of Canada, Mr. Hille sees a potential source of coke, and believes that marl beds, calcite veins and dolomite deposits of the Lake region, within close proximity to the ores, could furnish the flux. Mr. Hille describes the magnetite deposits of the Matawin

district as the most massive, most interesting, and perhaps the largest of which we have any knowledge. They are unproductive at present because of their low iron and high phosphorus content. After giving the following analysis:

Iron	30.66
Silica	47.86
Phosphorus	.11
Sulphur	.06

Mr. Hille remarks: "The iron contents of the ore are not very high here, but by going deeper into the deposit, where the ore escapes the influence of the meteoric water, a somwhat higher quality will probably be found." Anyone familiar with the nature of iron ore deposits can pass his own judgment upon the kind of science that is here officially thrust upon the public.

The magnetite deposits of the Atikokan district are regarded by Mr. Hille, as almost the counterpart of the Sudbury ores. "The Atikokan mineral area consists of a series of norite dikes containing pyrrhotite and magnetite in lenses." He also says that the iron bearing minerals of these dikes have been changed at the surface into iron ore. It is obvious then, that Mr. Hille recognizes that surface agencies may have enriched the iron deposits of the Atikokan district, whereas in the Matawin district, he believes that ore deposits lean at the surface may become richer in depth.

Turning to the Animikie, the author says, "the ore occurs in a rock formation which is known by different names in different localities; by us it is called the Animikie series. This series is as extensively developed here as in any other locality in the vicinity of Lake Superior." Mr. Hille finds the thickness of the Animikie to be only 200 feet in places, but much thicker in others. "In a few places where diamond drill holes and shafts have been put down we find that the depth of these rocks is as follows:

1. A diamond-drill hole 25 miles east of Whitefish Lake 1,200
2. A shaft four miles east of the same lake 700
3. Several diamond-drill holes northwest of the same lake 600
4. A diamond-drill hole near Iron Range Lake 1,000

All these holes were put down near the north margin of this formation, and, I might add, nearly every one of them yielded good indications of the occurrence of hematite ore."

Continuing the author says, "It is probably only a matter of time, and also of exploration, for us to find ore in our rocks in quantities as great as on the Mesabi. I can see no reason why this should not be the case since the geological and petrographical conditions are

identical, and we have the added advantage of the greater thickness of the Animikie series. It is surely incredible that an imaginary boundary line should have placed a limit on the deposits of hematitic ore, produced through natural phenomena, which were active in our district as well as that a few miles away from us."

The Animikie iron formation in Canada, although explored for a considerable time, is not known to have a deposit of sufficient size and merchantable quality to warrant mining. While portions of it are as thick as the iron formations of producing districts, as indicated by Mr. Hille, a not inconsiderable portion is so thin as to make the discovery of very large deposits, like those of the Mesabi, improbable. Furthermore, the Animikie is separated by numerous basic sills, which lessen still more the chances for finding deposits of very great magnitude.

While it is conceded that the Canadian iron deposits discussed by Mr. Hille may have economic possibilities, there appears to be no satisfactory basis for the predictions which he gives with an air of finality. This is regretable in a document which purports to be an official, authentic report published for the good of the commonwealth.

EDWARD STEIDTMANN.

The Ore Deposits of South Africa. Part I., Base Metals. J. P. JOHNSON. London, Crosby Lockwood & Son, 1908. Pp. 61, 10 diagrams.

In the preface the author states that "this little volume is intended to meet the demand of those technically connected with the mining industry, for a coördinated and condensed account of the ore deposits at present known in South Africa. It is also intended as a guide to the prospector."

Mr. Johnson has recognized a real need. Such information as has been obtainable concerning the ore deposits of South Africa has been fragmentary, generally confined to one or two deposits and scattered through numerous periodicals and transactions of societies, many of which have a limited circulation, so that it has often been difficult for a geologist or mining man to find the information he desired, even when it had been published.

Mr. Johnson treats titaniferous and chromiferous iron deposits, nickel, copper, cobalt, tin, molybdenum, tungsten, lead, mercury, antimony and iron—strangely enough beginning and ending his description of the minerals with iron ore. Condensation has been carried entirely too far for the needs of a geologist. For the prospector the treatment is perhaps full enough generally although important things have sometimes been left out; for instance, in treating tin deposits, such important details as the size of the cylindrical pipes at Potgietersrust are neglected

Naturally a large part of the book is made up of extracts from the work of other authors. In the main the references to these are full and sufficient. In this introduction Mr. Johnson gives a very good summary of the present views on the deposition of ore deposits from magmatic waters and as segregations in magmas. Like many others he does not find the classifications of other writers satisfactory and so proposes a new one. His classification is:

A. Magmatic Segregations.
B. Irregular Impregnations.

Reefs { C. Regular Impregnations of a Stratum.
D. Regular Impregnations of a Dyke.
E. Regular Impregnations along contact with a Dyke.
F. Regular Impregnations of the Walls of a Fissure.
G. Regular Crustifications (in fissures). } *Lodes*

H. Irregular Crustifications (in pockets).
I. Detrital Accumulations.

The author gives no definitions of the terms used, apparently believing them to be self-explanatory. The first and last divisions are perhaps unobjectionable, but the others, except possibly *B* and *G*, are rather hard to interpret. It is difficult to think of impregnations as regular. They are almost invariably irregular in thickness and richness, and almost as invariably irregular in composition from point to point. The author's work shows the difficulty of following his classification, as, in treating mercury, which he places under *F*, he states that in the deposit at Louw's Creek the ore "Occurs disseminated throughout a belt of crushed quartzite 4 to 5 feet wide and about 400 yards long." This would appear from the author's description to be more like a mineralized crushed zone or a narrow stockwork. The deposits of antimony in the Murchison Range are placed under *C*, but he says, page 47, "The antimony occurs . . . in lenticular veins . . . at intervals throughout the length of these kopjes, and each seems to occupy some minor stratigraphical position." It seems hardly proper to call large lenses of ore "regular impregnations."

The copper deposits are the most fully treated of any, as is perhaps fitting, owing to their importance. The author seems to have stopped short of the Katanga deposits, probably feeling that these were too far north to be considered in South Africa, although the English in general seem to consider them in that region.

In treating the mercury deposits 10 miles south of Melelane Station, it would have been helpful had the author stated whether or not they are connected with the large serpentine areas in which are found the magnesite deposits two miles south of Malelane. Close relation between mercury deposits and serpentine bodies is so common that the

proximity of the Malelane mercury and serpentine seems to demand notice.

In the Langverwacht placer tin deposits near Capetown, the author states that the cassiterite is derived from irregular impregnations in the surounding granite. In this he apparently disagrees with Griffiths[1] who states that tin ore not only occurs as an impregnation in the granite, but also in large quartz veins. Iron deposits in the sedimentary rocks, which Mr. Johnson states will probably be of future value, are dismissed with two short paragraphs. Tungsten deposits in South Africa, concerning which, so far as is known to the reviewer, nothing has been written, are barely mentioned.

His "Hints to Prospectors," with which the volume closes, have value, but would be better for the addition of simple tests for such minerals as those of tungsten, and for some changes in description. It is rather uncommon for cassiterite, wolframite and tantalite to resemble each other so closely that they are not readily differentiated by the eye alone, though the impression left by reading the "Hints" is that it cannot be done. Mr. Johnson advises the use of a sieve to jig gravels where heavy minerals are likely to be found, but for this purpose the ordinary American prospector would use a gold pan.

A map is much needed in works of this kind. South Africa, at best, is but little known to outsiders, and good maps are almost impossible to obtain. In fact, it is probable that no maps can be purchased which will show all the places to which Mr. Johnson refers, so that such a map should accompany the book.

In reading the book one is struck with the large amount of mining done by the Kaffirs. They work iron, copper, lead, and tin ores, and a number of the mines at present in operation have been located through these old workings. Owing to the extent of their excavations, one without much knowledge of the details feels inclined to attribute the workings to some people with a higher degree of civilization than the Kaffirs, such as one of the Semitic peoples to whom are credited the old gold workings in Mashonaland.[2]

The book is of very pleasing appearance, the paper is good and the type clear and readable.

FRANK L. HESS.

[1] Griffiths, Harry D., "Tin Mining in Cape Colony," abstract of paper read before the Chem., Metallurg. and Min. Society of South Africa. *Min. Jour.*, London, Vol. 83, p. 119.

[2] Bent, J. T., "Ruined Cities of Mashonaland," London, 1892.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN AND J. A. ALLAN.

METALLIFEROUS DEPOSITS.

COPPER, LEAD, AND ZINC.

Copper Mining and Prospecting on Prince William Sound. By U. S. GRANT and D. F. HIGGINS, JR. U. S. G. S. Bull. 379, 1909, pp. 87–96.

Describes properties largely developed since 1905 on Latouche Island, Knight Island, Galena Bay, Boulder Bay, Ellamar, Landlocked Bay, and Fidalgo Bay.

Mineral Resources of the Kotsina-Chitina Region, Alaska. By F. N. MOFFIT and A. G. MADDREN. U. S. G. S. Bull. 374, 1909, pp. 103.

Describes geography and history, general geology, and economic geology. The occurrence, source, and character of copper ores, the chief product, are considered and copper properties are described. Seven pages are devoted to gold, and one paragraph each to realgar and coal. L.

The Yernigton Copper District, Nevada. By F. L. RANSOME. U. S. G. S. Bull. 380, 1909, pp. 99–119.

Describes general geology, and the various mines and prospects. L.

The Tres Hermanes Mining District, New Mexico. By W. LINDGREN. U. S. G. S. Bull. 380, 1909, pp. 123–128.

Outlines general features and geology, and describes the mineral deposits (normal fissure veins in granite porphyry, and typical contact metamorphic deposits in limestone). L.

IRON AND MANGANESE.

The Hanover Iron-Ore Deposits, New Mexico. By S. PAIGE. U. S. G. S. Bull. 380, 1909, pp. 199–214.

Describes general geology and the distribution and character, mineralogy and chemistry, and genesis of the ores (chiefly contact metamorphic deposits of magnetite in limestone).

The Iron Ores of the Appalachian Region in Virginia. By E. C. HARDER. U. S. G. S. Bull. 380, 1909, pp. 215–254.

A general summary of results so far obtained. Classifies the iron ores of the Piedmont and Appalachian regions, and describes the occurrence of each type. L.

The Taylor Peak and White Pine Iron-Ore Deposits, Colorado. By E. C. HARDER. U. S. G. S. Bull. 380, 1909, pp. 188–198, with 4 small maps.

Gives general geology, the structure of the ore deposits, and the commercial importance of each district. The ore bodies in both districts are mostly small and of rather low grade. Transportation facilities are very unfavorable. L.

Tonnage Estimates of Clinton Iron Ore in the Chattanooga Region of Tennessee, Georgia, and Alabama. By E. F. BURCHARD. U. S. G. S. Bull. 380, 1909, pp. 169–187.

Gives for the different districts an outline of the facts on which the estimates are based, a table of analyses, and summary of tonnage estimates. Total available ore amounts to 86,569,000, and ore not available at present to 440,146,000, long tons.

Manganese Deposits of the United States. By E. C. HARDER. U. S. G. S. Bull. 380, 1909, pp. 250–277.

Considers sources, distribution and occurrence of the ores, the uses of manganese, and the manganese industry in the United States. L.

GOLD AND SILVER.

The Annual Report of the Ontario Bureau of Mines. 1908. Vol. XVII., Part II., by A. G. BURROWS. Pp. 31. Illustrated with maps. 1909. (1) The Gowganda and Miller Lake Silver Area. (2) The South Lorrain Silver Area.

A preliminary report on these two areas, including situation, the various Pre-Cambrian rocks which occur, the amount of work done to date and the future prospects. A.

The Fairbanks Gold Placer Region. By L. M. PRINDLE and F. J. KATZ. U. S. G. S. Bull. 379, 1909, pp. 181–200.

Gives geographic and geologic sketches, and a summary account of the development in mining methods since 1907. L.

Faulting and Vein Structure in the Cracker Creek Gold District, Baker County, Oregon. By J. T. PARDEE. U. S. G. S. Bull. 380, 1909, pp. 85–93.

Describes general geology with special attention to the faulting and vein system. Describes the Columbia and North Pole mine workings. L.

The Fortymile Quadrangle, Yukon-Tanana Region, Alaska. By L. M. PRINDLE. U. S. G. S. Bull. 375, 1909, pp. 52 with 5 plates and 2 figures.

Contains brief historical introduction, geographic sketch, geologic sketch (including origin of the gold), and describes the distribution and character of the placers.

Gold Placers of the Innoko District (Alaska). By A. G. MADDREN. U. S. G. S. Bull. 379, 1909, pp. 238–266.

Discusses geography and transportation at some length, and gives a full account of the economic geology. The deposits are mostly in frozen ground and there are no well defined pay streaks. Some scheme of hydraulic mining and a consolidation of all property interests are advised to bring about profitable results. L.

Gold Placers of the Ruby Creek Dstrict (Alaska). By A. G. MADDREN. U. S. G. S. Bull. 379, 1909, pp. 229–233.

Gives geographic and geologic sketch and describes occurrence of the gold. L.

Gold on Prince William Sound. By U. S. GRANT. U. S. G. S. Bull. 379, 1909, p. 97.

Brief mention of some promising prospects. L.

The Horn Silver District, Nevada. By F. L. RANSOME. U. S. G. S. Bull. 380, 1909, pp. 41–43.

Notes based on a day's visit, giving location, brief mention of rock formations, location and character of the principal veins. L.

The Iron Creek Region (Alaska). By P. S. SMITH. U. S. G. S. Bull. 379, 1909, pp. 302–354.

Describes geography, general geology, and economic geology (35 pp.), including placers and lode prospects, and water resources. L.

Mineral Resources of the Grants Pass Quadrangle and Bordering Districts, Oregon. By J. S. DILLER and G. F. KAY. U. S. G. S. Bull. 380, 1909, pp. 48–79.

General geology, by J. S. Diller, pp. 48–54. Mineral resources, by G. F. Kay, pp. 54–79, including gold-quartz veins, placer mines, copper

mines, and prospects of stibnite, josephinite, and cinnabar. Districts and individual mines are described under each of the above headings. L.

Mining in the Fair Haven District (Alaska). By F. F. HENSHAW. U. S. G. S. Bull. 379, 1909, pp. 355–369.

Gives a general idea of conditions and of recent mining developments. L.

Notes on the Bohemia Mining District, Oregon. By D. F. MCDONALD. U. S. G. S. Bull. 380, 1909, pp. 80–84.

Outlines physiography and general gelogy; briefly describes the ore bodies (fissure veins), hydrothermal metamorphism, secondary alteration and enrichment, and mining development. L.

Notes on the Economic Geology of South-eastern Gunnison County, Colorado. By J. M. HILL. U. S. G. S. Bull. 380, 1909, pp. 21–40.

Describes general geology, and the mineral resources of the various mining districts. L.

Placers of the Gold Hill District (Alaska). By A. G. MADDREN. U. S. G. S. Bull. 379, 1909, pp. 234–237.

A brief account of geography, geology, and economic development. L.

Preliminary Report on the Gowganda Mining Division, District of Nipissing, Ontario. By. W. H. COLLINS. Geol. Surv. of Canada. No. 1075, 47 pages with a map, 1909.

A preliminary report on this new district and its future prospects. The silver ores occur in narrow well defined veins filling fissures in the country rock which is diabase of Post Huronian age. The gangue minerals are quartz and calcite. The district is similar in many respects to that about Cobalt. A.

Round Mountain, Nevada. By F. L. RANSOME. U. S. G. S. Bull. 380, 1909, pp. 44–47.

Contains results of a brief visit. Describes megascopic character of the principal rock (rhyolite), the workings of the sunnyside mine, and the character and value of its ore. Mentions other workings, including placer ground yielding an average of $5 a yard. L.

Ursprung des Goldes in den Randconglomeraten. By F. W. VOIT. Monatsber. d. Deutsch. Geol. Ges. 1908, pp. 107–119, with 5 figs. and 1 pl.

TIN.

Stanhills Tinfields. By B. DUNSTAN. Queensland Govt. Min. Jour. June 15, 1908.

The Tin, Molybdenum, and Lead Occurrences near Potgretersrust. By J. P. JOHNSON. Trans. Geol. Soc. So. Africa. Vol. X., 1908, pp. 115–119.

NON-METALS.

ASPHALT.

Grahamite Deposits of Southeastern Oklahoma. By J. A. TAFF. U. S. G. S. Bull. 380, 1909, pp. 286–297.

Describes location and occurrence, physical features of the region, stratigraphy of rocks containing grahamite, structure, and descriptions of deposits by localities. The deposits occur as veins in sandstone and shale. L.

An Occurrence of Asphaltite in Northeastern Nevada. By R. ANDERSON. U. S. G. S. Bull. 380, 1909, pp. 283–285.

Describes character and occurrence (in veins) of the asphaltite, and gives brief conclusion as to the possible occurrence of oil. L.

CLAYS.

Notes on the Clays of Florida. By G. C. MATSON. U. S. G. S. Bull. 380, 1909, pp. 346–357.

Brief descriptions, with analyses and some physical tests, of the several clay beds in the Tertiary and Quaternary of Florida. L.

COAL, LIGNITE, AND PEAT.

Contributions to Economic Geology, 1907. Part II. Coal and Lignite. M. R. CAMPBELL, Geologist in Charge. U. S. G. S. Bull. 341, 1909, pp. 444, with 25 plates and 7 figures.

The introduction by Mr. Campbell classifies coal areas into provinces, regions, fields and districts; gives a general outline of the geologic work done, and of the chemical study of coal. The other papers comprising the volume are also published separately as Bulls. 341A, B and C, the contents of which are noted below. L.

Investigations of the Coal Fields of Montana and North Dakota. U. S. G. S. Bull. 341 A, 1909, pp. 15–122.

Mont., by R. W. Stone, p. 78. The Red Lodge coal field, Mont., by A. G. Leonard and C. D. Smith, p. 15. The Miles City coal field, Mont., by A. J. Collier and C. D. Smith, p. 36. The Bull Mt. coal field, Mont., by L. H. Woolsey, p. 62. Coal near the Crazy Mts., Mont., by R. W. Stone, p. 78. The Red Lodge coal field, Mont., by E. G. Woodruff, p. 92. The Lewistown coal field, Mont., by W. R. Calvert, p. 108. L.

Investigations of the Coal Fields of Wyoming by The United States Geological Survey in 1907. By J. A. TAFF, E. W. SHAW, C. W. WASHBURNE, E. G. WOODRUFF, E. E. SMITH, M. W. BALL, and A. R. SCHULTZ. U. S. G. S. Bull. 341–B, 1909, pp. 123–282.

Contents: The Sheridan coal field, Wyoming, by J. A. Taff, p. 123. The Glenrock coal field, Wyoming, by E. W. Shaw, p. 151. Coal fields of the northeast side of the Big Horn Basin, Wyoming, and of Bridger, Mont., by C. W. Washburne, p. 165. Coal fields of the southwest side of the Big Horn Basin, Wyoming, by E. G. Woodruff, p. 200. The eastern part of the Great Divide Basin, Wyoming, by E. E. Smith, p. 220. The western part of the Little Snake River coal field, Wyoming, by M. W. Ball, p. 243. The northern part of the Rock Springs coal field, Sweetwater County, Wyo., by A. R. Schultz, p. 256. L.

Investigations of the Coal Fields of Colorado, New Mexico, Utah, Oregon, and Virginia by the United States Geological Survey in 1907, with a Bibliography of Survey Papers relating to Coal, Coke, Lignite, and Peat. U. S. G. S. Bull. 341–C, 1909, pp. 283–436.

Contents: Coal fields of northwestern Colorado and northwestern Utah, By H. S. Gale, p. 283. The Grand Mesa coal field, Colorado, by W. T. Lee, p. 316. The coal field between Gallina and Raton Spring, N. Mex., in the San Juan coal region, by J. H. Gardner, p. 335. The coal field between Durango, Col., and Monero, N. Mex., by J. H. Gardner, p. 352. The coal field between Gallup and San Mateo, N. Mex., by J. H. Gardner, p. 364. The Harmony, Colob, and Kanab coal fields, southern Utah, by G. B. Richardson, p. 379. The Rogue River valley coal field, Oregon, by J. S. Diller, p. 401. A coal prospect on Willow Creek, Morrow County, Oreg., by W. C. Mendenhall, p. 406. The Pocket coal district, Virginia, in the Little Black Mountain coal field, by C. A. Fisher, p. 409. Classified list of papers dealing with coal, coke, lignite, and peat, except those on Alaska, by W. T. Lee and J. M. Nickles, p. 419.

Geology of the Great Falls Coal Field, Montana. By C. A. FISHER. U. S. G. S. Bull. 356, 1909, pp. 85, with 12 plates and 2 figures.

Bibliography, pp. 7–14; topography, pp. 14–20; descriptive geology, pp. 21–50; economic geology, pp. 50–82, includes geologic occurrence, location and extent, character and thickness, and development of coal, descriptions of mines. The coal is of lower cretaceous age, medium-grade bituminous, and surpasses or compares favorably with coals in southern Mont., northern Wyoming and the Black Hills region. The coal field, owing to geographic position is destined to become the most important coal-mining district in north-central Montana. L.

Reconnaisance of the Book Cliffs Coal Field between Grand River, Colorado, and Sunnyside, Utah. By G. B. RICHARDSON. U. S. G. S. Bull. 371, 1909, pp. 54, with 10 plates and 4 figures.

Topography 5 pp., descriptive geology 12 pp., occurrence and thickness of coal 18 pp., amount available, character, use, and development 6 pp. The coals are medium-grade bituminous and rank favorably with coals of the Rocky Mts. and Mississippi Valley. They depend at present on a local market, and are but little developed. L.

Binders for Coal Briquets. Investigations made at the fuel-testing plant, St. Louis, Mo. By J. E. MILLS. U. S. G. S. Bull. 343, 1909, pp. 56 with 1 figure.

Describes the characteristics of good briquets, conditions governing the use of binders. Laboratory investigations of various binders, experiments in briquetting without binders, and results of tests in briquetting different coals. Concludes with a bibliography. L.

Results of Purchasing Coal under Government Specifications. By J. S. BURROWS, with a paper on **Burning the Small Sizes of Anthracite for Heat and Power Purposes.** By D. T. RANDALL. U. S. G. S. Bull. 378, 1909, pp. 44.

The first paper explains a general plan for purchases, contracts for 1909, and results for 1907–8. The second paper shows how small sizes of anthracite may give as good results as large sizes. L.

Peat Deposits of Maine. By E. S. BASTIN and C. A. DAVIS. U. S. G. S. Bull. 376, 1909, pp. 127.

Gives a general account of peat formation (pp. 8–17), discusses the origin and economic value of salt marshes (pp. 19–21); discusses factors influencing successful utilization of a peat deposit (pp. 22–29), peat as a fuel, as raw material for other than fuel manufacture, and as a useful material in agriculture (pp. 30–60); gives methods of testing Maine bogs, estimation of tonnage of machine peat, and explanation of analyses (pp. 60–64); describes localities (pp. 64–110); gives analyses, the composition of foreign and domestic peats (pp. 114–122), and concludes with a bibliography. L.

MICA.

Mica Deposits of South Dakota. By D. B. STERRETT. U. S. G. S. Bull. 380, 1909, pp. 382–397.

Gives brief introductory reference to local and general demand and supply. Describes general geology of the region, occurrence of mica (in pegmatite), the various mines, and briefly discusses the origin of the pegmatite (identical with that of pegmatites in general). L.

PETROLEUM.

Les Gisements Petrolifères de la Roumanie. By L. DEMARET. Ann. des Mines de Belgique. T. XIII., 2 Liv., 1908, pp. 55 with maps.

RARE ELEMENTS.

Tin, Tantalum, and Tungsten Deposits of South Dakota. By F. L. HESS. U. S. G. S. Bull. 380, 1909, pp. 131–163.

Gives a general introduction, and considers the metals in the above named order, describing claims, and discussing their value. The metals are closely related genetically, and occur in scattered shoots of limited size, workable only on a small scale. L.

Note on a Wolframite Deposit in the Whetstone Mountains, Arizona. By F. L. HESS. U. S. G. S. Bull. 380, 1909, pp. 164–165.

Gives location and description of ore found in quartz vein cutting granite near the latter's intrusive contact with mica schist and limestone. Quantity of ore thus far found is too small to pay for working. L.

SALINES.

Sodium Sulphate in Soda Lake, Carriso Plain, San Luis Obispo County, California. By R. ARNOLD and H. R. JOHNSON. U. S. G. S. Bull. 380, 1909, p. 369–371.

Briefly describes location, occurrence, chemical nature, and commercial development. Material is very abundant, but transportation facilities at present are inadequate. L.

SULPHUR.

Sulphur Deposits near Thermopolis, Wyo. By E. G. WOODRUFF. U. S. G. S. Bull. 380, 1909, pp. 373–380.

Gives location and extent, and geologic relations; describes structure, the occurrence of hot springs, the nature and occurrence of travertine and sulphur, origin of the sulphur ore (replacement of limestone along hot spring courses), mining smelting, marketing, and production. L.

STRUCTURAL MATERIALS.

Cement Materials near Havre, Mont. By L. J. PEPPERBERG. U. S. G. S. Bull. 380, 1909, pp. 327–336.

Gives location and extent, outline of geology, and composition of cement materials. Discusses control of the mix, amount of available limestone, fuel supply, water, market facilities, market and competition. The materials are of proper composition, and the fact that a

large percentage of CaO in the limestone is in the form of silicate is regarded as favorable. Careful prospecting is advised before any plant is erected. L.

The Fire-Resisting Properties of the various Building Materials. By R. L. HUMPHREYS. U. S. G. S. Bull. 370, 1909, pp. 99, with 14 tables, 39 plates, and 32 figures.

Describes scope and character of investigations, gives a synopsis of tests, states the sources of material tested, describes apparatus, preparation of materials tested, method of conducting tests, and the results of tests. L.

Ganister in Blair County, Pennsylvania. By C. BUTTS. U. S. G. S. Bull. 380, 1909, p. 337–342.

"The name gainster is derived from the German ganster, meaning a spark, and owes its application to the fact that the rock will give a spark when struck with iron." The ganister of Blair Co. is a nearly pure silica rock. The paper gives analyses and properties, geologic occurrence (silicified beds in Medina formation), methods of working, qualities for manufacture of refractory brick, processes of manufacture, character and uses of the brick. L.

Marble Prospects in the Chiricahua Mountains, Arizona. By S. PAIGE. U. S. G. S. Bull. 380, 1909, pp. 299–311.

Briefly describes first the geography and topography and general geology; second the distribution, composition and appearance, jointing, weathering, utilization, and transportation, a table of tests is appended.

The Niobrara Limestone of Northern Colorado as a possible source of Portland Cement. By G. C. MARTIN. U. S. G. S. Bull. 380, 1909, pp. 314–326.

Gives general geologic relations, requirements for cement materials, descriptions of local materials, and analyses. There is much rock of the requisite quality, but conditions of quarrying, manufacture, and transportation are not considered. L.

Structural Materials in Parts of Oregon and Washington. By N. H. DARTON. U. S. G. S. Bull. 387, 1909, pp. 33, with 9 plates and 1 figure.

Describes the several geologic formations; discusses the availability of sand and gravel, broken rock, clay, building stone, plaster, cement materials, and limestone. L.

WATER.

Geology and Water Resources of The Harney Basin Region, Oregon. By G. A. WARING. U. S. G. S. Water-Supply Paper 231, 1909, pp. 93, with 5 plates.

Nine pages devoted to geography, 15 to general geology and physiography, 11 to a discussion of surface water supply, 3 to underground water, 1 to conservation of the water supply, remainder to details of the several basins. L.

Surface Water Supply of Nebraska. By J. C. STEVENS. U. S. G. S. Water Supply Paper, 230, 1909, pp. 251, with 6 plates and 5 figures. Fifteen pages devoted to explanations of units and definitions, stream measurements, methods of computation, and accuracy and reliability of data; 11 to relation of rainfall to run-off, remainder to a compilation of hydrographic data collected in Nebraska, including 1906, arranged according to the principal drainage basins. The relation between rainfall and run-off differs markedly from streams in other portions of the United States. L.

The Mineral Content of Illinois Waters. By E. BARTOW, J. A. UDDEN, S. W. PARR, and G. T. PALMER. Illinois State Geol. Surv. Bull. 10, 1909, pp. 192, with 9 plates and 1 figure. University of Illinois, Urbana, 1909.

Contents: Introduction, historical statement and distribution of waters analyzed; geological classification of the waters of Illinois; classification of mineral waters, according to physical and chemical properties; methods and interpretations; boiler waters; mineral springs of Illinois; tables of analyses. L.

Some Desert Watering Places in Southeastern California and southwestern Nevada. By W. C. MENDENHALL. U. S. G. S. Water-Supply Paper, 224, 1909, pp. 98, with 4 plates. (Stock exhausted.)

Underground waters of Southern Maine. By F. G. CLAPP with **Records of Deep Wells**, by W. S. BAYLEY. U. S. G. S. Water-Supply Paper 223, 1909. Pp. 268, with 24 plates and 4 figures.

Briefly discusses settlement and development, surface features, drainage, and relations of climate to underground water conditions (pp. 17–21); gives a general account of underground water conditions (pp. 23–27), of the water-bearing rocks and surface deposits of the region (pp. 28–42), and of the recovery of underground water (pp. 43–63); gives notes on well-drilling, public supplies, and the composition of the underground waters (pp. 63–92), gives descriptions of underground waters by counties (pp. 92–236); concludes with a list of deep well records (pp. 238–258). L.

Water-Supply Investigations in Seward Peninsula, 1908. By F. F. HENSHAW. U. S. G. S. Bull. 379, 1909, pp. 370–401.

Briefly describes the several basins, giving discharge records, and rainfall records. L.

Water-Supply Investigations in the Yukon-Tanana Region, Alaska, 1907 and 1908. Fairbanks, Circle, and Rampart Districts. By C. C. COVERT and C. E. ELLSWORTH. U. S. G. S. Water-Supply Paper 228, pp. 108, with 7 plates and 3 figures, 1909.

Briefly describes every area; considers conditions affecting water-supply; describes the several drainage basins, giving discharge measurements; compares discharge of the different areas; discusses hydraulic development; proposes use of water power for electric-transmission; suggests a means of artificial storage and conservation. L.

ORE DEPOSITS.

The Formation and Enrichment of Ore-Bearing Veins. By G. J. BANCROFT. Bull. A. I. M. E. No. 31, July, 1909, pp. 581–590.

Lays particular emphasis on the efficiency of chlorine as an agent in ore formation. L.

Die Genesis der Pinolit-magnesite, Siderite, und Ankerite der Ostalpen. By K. A. REDLICH. Tschermaks Min. u. Pet. Mitt. Bd. 26, 6s.

REGIONAL REPORTS.

West Virginia Geological Survey, Vol. IV., 1909. By C. P. GRIMSLEY.

Part I., The Iron Ores of West Virginia, pp. 1–285. Part II., Salt in West Virginia, pp. 286–354. Part III., The Sandstones of W. Va., pp. 355–595. L.

Mineral Resources of Alaska. Report of Progress of investigations in 1908. By A. H. BROOKS and others. U. S. G. S. Bull. 379, 1909, pp. 418, with 10 maps and 21 figures.

Contains administrative report, and a discussion of the mining industry in 1908. By A. H. Brooks. Other papers are listed elsewhere in this bibliography. L.

Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek Regions. By F. H. MOFFIT. U. S. G. S. Bull. 379, 1909, pp. 153–160.

A report of progress since 1906. L.

Mineral Resources of the Nabesna-White River District. By F. H. MOFFIT and A. KNOPF. U. S. G. S. Bull. 379, 1909, pp. 161–180.

General description; geology; mineral resources, including copper, gold, and lignite. The region is easily prospected. The occurrence

of native copper associated with zeolites in amygdaloidal basalt is of especial interest, and warrants further development. L.

Mineral Resources of Southwestern Alaska. By W. W. ATWOOD. U. S. G. S. Bull. 379, 1909, pp. 108–152.

Describes the geology and distribution of known deposits of coal (mostly), petroleum, gold, and copper. L.

Mining in Southeastern Alaska. By C. W. WRIGHT. U. S. G. S. Bull. 379, 1909, pp. 67–86.

Gives account of conditions in the Juneau, Sitka, Wrangell, and Ketchikan districts. L.

Recent Developments in Southern Seward Peninsula. By P. S. SMITH. U. S. G. S. Bull. 379, 1909, pp. 267–301.

Describes recent enterprises, work recently completed, and projects and tendencies noted in the region. Nome, the Solomon and Casadepaga, Council, Kougarok, and Port Clarence, are the regions considered. L.

Notes on the Geology and Mineral Prospects in the vicinity of Seward, Kanai Peninsula. By U. S. GRANT and D. F. HIGGINS, JR. U. S. G. S. Bull. 379, 1909, pp. 98–107.

Describes geology, copper prospects, and gold prospects. L.

Summary Report of the Geologcal Survey Branch of the Department of Mines, for the year 1908. Ottawa, Canada. 211 pages.

Summarizes the work carried on during the year. Gives brief reports from the various individuals in charge of field parties, of the nature of the field work conducted during the year. A.

Annual Report of the Ontario Bureau of Mines. Vol. XVII. 356 pages, 5 maps and numerous illustrations, 1908.

Outlines the work being carried on in Ontario. Briefly describes the mines in operation. A description is given of the geology of Thunder Bay, which seems to be of slight economic importance.

The Iron Ranges about Lake Nipigon are quite extensively described and discussed by A. P. Coleman and E. S. Moore. A large portion of this report is occupied by a detailed description of the Iron and Steel Industry of Ontario, by G. C. MacKenzie including modes of occurrence and methods of extraction. This report contains numerous excellent illustrations. A.

UNCLASSIFIED.

Bibliography of North American Geology for 1906 and 1907, with Subject Index. By F. B. WEEKS and J. M. NICKLES. U. S. G. S. Bull. 372, 1909, pp. 317.

Gives a list of serials examined, a bibliography arranged according to authors, an index, and lists of chemical analysis, geologic formations described, minerals described, and of rocks described. L.

Contributions to Economic Geology 1908. Part I., Metals and Non-Metals, except Fuels. C. W. HAYES and WALDEMAR LINDGREN, Geologists in charge. U. S. G. S. Bull. 380, 1909, pp. 406, with 2 plates and 32 figures.

The papers contained are listed under the several metals and non-metals in this bibliography. All papers on any single product are also published separately. A bibliography of U. S. G. S. publications accompanies each group of papers. L.

Mineral Resources of the United States, 1908. U. S. G. S.

Separate chapters on monazite and zircon; salt and bromine; bauxite and aluminum; phosphate rock; slate; petroleum; chromic iron ore; cement; mica; talc and soapstone; asbestos; manganese ores; gypsum and gypsum products; fluorspar and cryolite; barytes and strontium; quartz and feldspar; sulphur and pyrite. L.

Papers on the Conservation of Mineral Resources. (Reprinted from report of the National Conservation Commission, Feb., 1909.) U. S. G. S. Bull. 394, 1909, pp. 214, with 12 plates and 2 figures.

Contains the following papers: Coal fields of the United States, by M. R. Campbell and E. W. Parker, pp. 7–26. Estimates of future coal production by H. Gannett, pp. 27–29. Petroleum Resources of the United States, by D. T. Day, pp. 30–50. Natural-gas resources of the United States, by D. T. Day, pp. 51–61. Peat resources of the United States, exclusive of Alaska, by C. A. Davis, pp. 62–69. Iron ores of the United States, by C. W. Hayes, pp. 70–113. Resources of the United States in gold, silver, copper, lead, and zinc, by W. Lindgren, pp. 114–156. The Phosphate deposits of the United States, by F. B. Van Horn, pp. 157–171. Mineral resources of Alaska, by A. H. Brooks, pp. 172–208. L.

SCIENTIFIC NOTES AND NEWS[1]

THE UNITED STATES GEOLOGICAL SURVEY has had fourteen parties in Alaska this summer. These parties comprised twelve geologists, seven topographers, and three engineers. Two parties have been at work in southeastern Alaska, one in the Copper River region, two in the Matanuska coal region, one in the eastern part of the Kenai Peninsula, two in the Iliamna Lake region, two in the Yukon-Tanana region, one in the Koyukuk and Chandalar districts, one in the Norton Bay region, and one in Seward Peninsula.

These surveys and investigations are carried on under the direction of Alfred H. Brooks, who left Seattle for Cordova on the first of July. From Cordova he proceeded up Copper River and made a brief visit to the Nizina district. He then went by overland trail to Fairbanks, and later paid a visit to the Berners Bay and Eagle River districts, in southeastern Alaska.

Southeastern Alaska.—General reconnaissance work in the mining districts of southeastern Alaska having been completed, the present investigations include more detailed surveys. Adolph Knopf, geologist, began work in the Berners Bay region on May 19, studying the geology and ore deposits in detail. On the completion of this work he started to Eagle River and there began work on a similar investigation.

J. W. Bagley, with one assistant, made a detailed topographic survey of the Eagle River mining district. He then extended his work southward to connect with previously surveyed areas near Juneau.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

Copper River Region.—At the close of last year the general investigation of the two copper belts of the Copper River region was completed, and it now remains to make a more detailed study of the regions of present greatest economic importance. The area first to be investigated lies at the east end of the Chitina-Kotsina belt. This field not only affords the best exposures but is also the region where greatest depth has been reached in developing the ore bodies; hence it will yield more facts than other parts of the district and was therefore chosen for the first investigation. It is hoped that it will be possible later to map in detail the other important parts of this copper belt. Meanwhile it is expected that the work in this field will throw important light on the occurrence of copper ores throughout the region.

F. H. Moffitt and S. R. Capps are doing this work.

Kenai Peninsula.—U. S. Grant and D. F. Higgins sailed from Seattle on June 8 for Seward to begin a reconnaissance of the eastern part of Kenai Peninsula. Much prospecting has been done in this field during the last few years, and it is expected that Mr. Grant's investigations will be of value to the prospectors. He will use a large launch for traveling, as the work will necessitate passing many headlands that are open to the full sweep of the Pacific. It is expected that Mr. Grant will be able to complete the preliminary examination of the entire southeastern and southern coast line of the Kenai Peninsula.

Matanuska Coal Field.—The policy of mapping the Alaskian coal fields in detail has been continued in the Matanuska field this season. R. H. Sargent, with one assistant and six men, began work about the middle of June. This force was divided into two parties. Mr. Sargent's task was to make a detailed topographic map of the most important part of the Matanuska coal field, which will serve as a base map for detailed geologic investigations during 1910.

Ilamna Lake Region.—West of Cook Inlet is a large unsurveyed tract in which, it is reported, there have been discoveries of copper lode deposits and placer gold. In accordance with the

policy of covering new fields as rapidly as possible, the Geological Survey this year dispatched a double party to begin the survey of this extensive area. This party was in charge of D. C. Witherspoon, topographer, with whom was associated G. C. Martin, geologist. The party landed at Iliamna Bay May 14. It is expected that they were able to begin their westward march about the first of June. F. J. Katz assisted in the geologic work and C. E. Griffin in the topographic survey. Besides these there were seven other men. Canoes were used on the lakes and horses in land travel.

Yukon Region.—The extensive area lying between the Yukon and Tanana has been the subject of investigation for several years. A reconnaissance map of this area is now completed, and much of the geologic work has also been done, but a considerable tract still remains to be covered. This work has been continued by L. M. Prindle, assisted by B. L. Johnson. The party landed at Circle about the middle of June to go southwestward, reaching Fairbanks about the first of August. Thence a trip was made to the region southeast of Fairbanks, and later in the year the work was extended into the area northwest of Fairbanks.

The investigation of the surface water supply needed for placer mining in this field was begun in 1907, and as it is necessary to obtain records of stream flow for a number of years before any generalizations can be made as to the run-off, these investigations have been continued this year. C. E. Ellsworth, who was detailed to this work, reached Fairbanks over the trail about the first of April and has since been engaged in stream measurements in the Fairbanks, Baker, and Rampart districts.

The first survey of the Chandalar and Koyukuk districts was made in 1899 by F. C. Schrader and T. G. Gerdine. This was the summer in which gold was discovered in this field. Since that time the Koyukuk district has been a continued producer in a small way, but in 1907 more valuable placers were found there and some workable placers were found in the Chandalar district. This fact led to a demand for further work in this field, which was carried on by A. G. Maddern. Mr. Maddern reached the

Chandalar district in the early part of July and later made his way overland to the Koyukuk district. He had one man with him and used horses for carrying his supplies and equipment.

Norton Bay Region.—Between the lower Koyukuk and Seward Peninsula there is a belt about 150 miles wide which is practically unexplored. It is possible that this area may contain deposits of gold and coal. With the view of obtaining information on this point, P. S. Smith, assisted by H. M. Eakin, carried on an exploratory survey westward from Nulato to Norton Bay, and thence to Council. The party was equipped with six horses and included two men, besides the geologists.

Seward Peninsula.—The Geological Survey has done more work in Seward Peninsula than in any other part of Alaska. The entire field has been covered by geologic and topographic reconnaissance maps, and some of the more important areas have been mapped in detail. In addition to this, special reports have been published on the tin deposits and on the gold placers.

Investigation of the water resources—an important feature to the placer miner—was begun in 1906. As, however, it takes a number of years to obtain sufficient records to determine the rainfall, even approximately, this work is being continued through another year. F. F. Henshaw, assisted by G. L. Parker, continued stream gaging in some of the most important mining districts.

DEPARTMENT OF MINES, DOMINION OF CANADA.

It will be remembered by readers of ECONOMIC GEOLOGY that the Department of Mines which has recently been constituted in the Dominion of Canada consists of two branches, (*a*) the Geological Survey and (*b*) the Mines Branch. The Geological Survey has charge of all geological work, whether this be exploratory, areal mapping or economic geology, while the latter branch has assigned to it mineral statistics and investigations into the technology of the various industries which are connected with the mineral resources of the country. The department has over it a Minister of the Crown under whom Dr. A. P. Low holds the

position of deputy minister, while Mr. R. W. Brock is director of the Geological Survey and Dr. E. Haanel is director of the Mines Branch.

The work of both these branches of the department has been carried on very actively during the past year. This work may be considered under the heads of the respective divisions.

(*a*) *Geological Survey.*—In the Yukon and MacKenzie River districts the survey had three parties at work. Mr. D. D. Cairnes and his party spent the field season near White Horse in making an examination of the coal deposits of the Tantalus locality. Mr. Joseph Keele, who spent the winter of 1907–08 near the head of the Pelly River, crossed the head waters of the Gravel River and during the summer made a reconnaissance of the district traversed by that river down to its junction with the MacKenzie. An ethnological expedition under the joint auspices of the Geological Survey of Canada and the American Museum of Natural History made a journey down the MacKenzie River and is spending the present winter among the Eskimo about the Arctic Sea. It is believed that from this expedition much information concerning the geography and mineral resources of the region is likely to be obtained, as well as much additional information with regard to the ethnology of this remote portion of the Dominion.

Six parties carried on field work for the survey in the Province of British Columbia. Mr. R. G. McConnell made a detailed survey of the northern portion of Texada Island, a district which has come into prominence on account of the copper and iron deposits which exist there. Mr. R. P. D. Graham, of McGill University, made a geological examination of the Pacific coast inlets between Kingscanie Inlet and Bella Coola. This work forms a continuation of that which was begun in the south by Mr. LeRoy in 1906 and carried farther north by Mr. Bancroft in 1907. This district has an especial interest from a geological standpoint on account of the phenomena developed by the intrusion of the great Coast Range bathylith and the mineral deposits occurring here in connection with this intrusion. Mr. W.

W. Leach explored the Bukeley Valley near the route which will be taken by the new Grand Trunk Pacific Railway. This district is already known to possess important economic resources in the form of numerous and thick coal seams, as well as deposits of lead and copper. A systematic survey of Vancouver Island is being undertaken by the Survey, the work being started last summer at the southern end of the island by Mr. C. H. Clapp. The survey is also making a study of the fauna and flora of the island, this work being in charge of Mr. John Macoun, the Dominion botanist, who also visited the mines of the Rossland camp for the purpose of studying the fungi, which here rapidly destroy the mine timbers, with the view of ascertaining how this destruction can best be prevented.

Mr. Charles Camsell completed an investigation begun in the previous year on the gold-arsenic ores of Camp Hedley in the Similkameen district.

Mr. O. E. LeRoy mapped and made a detailed study of the ore deposits at Phœnix in the boundary district of British Columbia.

The survey also had three parties in the field in Alberta and Saskatchewan. The first of these under Mr. Malloch made a geological survey of the Big Horn coal area on the Brazeau River. The second, under Mr. Dowling, made a general study of the coal supply of the Province of Saskatchewan and a portion of Alberta. The third under Mr. McInnis made a reconnaissance along the route of the proposed Hudson Bay Railway where it follows the Churchill River between Lac la Rouge and Indian Lake.

In the district of Keewatin Mr. O. Sullivan made an instrumental survey along a stretch of 250 miles of the coast of Hudson Bay, thus completing the survey of the bay in question.

In the Province of Ontario four parties were engaged in field work. Dr. A. W. G. Wilson completed the mapping of an area along the National Transcontinental Railway near Lake Nipigon. Mr. W. H. Collins made a geological examination of the upper portion of the Montreal River district. Much at-

tention has recently been attracted to this district owing to the discovery there of silver-cobalt ores similar to those which occur in the district about Cobalt. Messrs. F. B. Taylor, Goldshwaite and W. A. Johnson were engaged in a study of the superficial geology of the region of the Great Lakes, this work being a continuation of that carried out by Messrs. Taylor and Goldshwaite in previous years to the south of the international boundary. Mr. E. D. Ingall spent the season in the examination of the gas and oil wells of south Ontario.

In the province of Quebec Mr. M. E. Wilson continued his examination of the country east of Lake Temiscaming, which has also recently attracted much attention owing to the fact that the Pre-Cambrian rocks of the Cobalt district here cross into the province of Quebec. Mr. J. A. Dresser made an examination of the district between the National Transcontinental Railway and the state of Maine from the vicinity of Quebec city to the border of the province of New Brunswick. This comparatively unknown district is of economic interest on account of the fact that it is situated on the strike of the serpentine belts carrying great deposits of asbestos and chromic iron ore in the more southern portion of the province of Quebec.

In the province of New Brunswick Dr. George A. Young made a detailed study of the deposits of iron ore recently discovered near Bathurst on the Baie des Chaleurs, which are of great extent and promise to be a very important factor in the iron trade of eastern Canada in near future.

Dr. R. W. Ells was during the year sent to Scotland to make a special study of the oil shale industry with a view to the utilization of the great bodies of similar shale found in Albert County, New Brunswick.

Mr. L. Lambe was engaged in a study of the vertebrate fossils and Mr. W. J. Wilson in the collection of plant remains from the supposed Devonian strata of the Province of New Brunswick.

In Nova Scotia Messrs. H. Fletcher, E. R. Faribault and H. M. Ami during the summer continued their investigations in various parts of the province.

In the province of Prince Edward Island a deep bore hole was put down through the Upper Carboniferous strata with a view to determining whether the coal measures occurring in the adjacent province of New Brunswick passed beneath the island in question, and if so, whether they contained workable deposits of coal.

(*b*) *The Mines Branch.*—The investigations which were carried out by the Mines Branch during the past year include an inquiry into the methods employed in treating and preparing peat for the market in the various countries in Europe in which this fuel has been most successfully utilized. The department also carried out magnetic surveys of certain iron ore bodies.

The mineral statistics of the dominion were also compiled and an elaborate report on the mining and metallurgical industries of Canada was completed and published.

An important investigation into the coals of Canada was also undertaken by the department, large lots of these coals being collected from all the important coal fields and shipped to the laboratories of McGill University, Montreal, where a special gas producer plant was installed. In this plant the suitability of these coals for employment in producer plants is tested and the efficiency of each coal in this respect determined. Tests are also made of the calorific value of these fuels as well as their suitability for steam production. These experiments, which have been very extensive and very thorough, are still in progress but will be completed during the coming spring.

In connection with this investigation experiments were also made for the determination of the coking value of these coals and the improvement in quality which could be effected in certain of them by washing.

These tests are being carried out for the department by Professors R. J. Durley and J. B. Porter.

A large amount of work was also done in the chemical laboratories of the Mines Branch which undertakes the chemical work for the whole Department of Mines.

As mentioned above, a report on the mining and metallurgical

industries of Canada was issued during the year. This is a volume of xvi + 972 octavo pages. The various industries are treated by provinces. The volume gives an account of the organization, location and development of the property of all the mining and smelting companies in actual operation in the Dominion and is illustrated by numerous plates accompanied by six maps. The price of this report has been fixed at $1.00 and it may be obtained on application to the director of the Mines Branch of the Department of Mines at Ottawa.

F. D. ADAMS.

MR. A. F. CRIDER has resigned the directorship of the State Geological Survey of Mississippi and Dr. E. H. Lowe, formerly professor of geology in the University of Mississippi, has been elected to the position.

MR. S. F. EMMONS, of the U. S. Geological Survey, has received the doctorate of science from Harvard University. He is now in Washington, D. C.

THE Rhode Island legislature at the last session appropriated $2,500 annually for three years for a survey of the naural resources of the state. The work was placed under the general charge of the Bureau of Industrial Statistics, Colonel George H. Webb, commissioner, who has appointed Professor Charles W. Brown, head of the department of geology at Brown University, to take immediate direction of the survey. Mr. Nelson C. Dale, A.M., and I. R. Sheldon, '10, have been appointed field assistants.

M. R. CAMPBELL AND E. C. BARNARD made their headquarters for the summer at the Denver office of the U. S. Geological Survey, 425 Commonwealth Building.

W. R. CALVERT, assisted by Messrs. Barnett, Pishel and Beekley of the Geological Survey completed the classification of lands in the Cheyenne Indian reservation, South Dakota, about July 20.

DR. ALBERT JOHANSENN, of the U. S. Geologiial Survey, began his summer field work in the Black Hills, near Rapid City, S. D.

C. A. FISHER made a study of the coals in Central Appalachian field this summer. Early in July he spent a few days in the New River field and later will visit the Pocahontas field.

MR. WALTER HARVEY WEED has entered into partnership with Mr. Frank H. Probert. The firm will make a specialty of the examination of mining properties, geological surveys, etc., and will do business under the name of Weed and Probert. The offices are at 42 Broadway, New York, and The Central Building, Los Angeles, California.